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OBJECTIVE DIGITAL ANALYSIS OF BATHYTHERMOGRAPH TRACES

by

Eric Francis Grosfils

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THESIS

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Eric Francis Grosfils

December 1968

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OBJECTIVE DIGITAL ANALYSIS OF BATHYTHERMOGRAPH TRACES

by

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requirements for the degree of

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ABSTRACT

There is a need for a fast method of analyzing bathythermograph traces and this need is approached by the means of a high-speed digital computer. The theory behind the computer program is outlined. Both synthetic and real data cases are run as examples using both data card decks and magnetic tape inputs. The program has been designed to read digitized bathythermograph traces and then analyze them objectively by Gaussian and non-Gaussian methods for the top, center, and base of the main thermocline. Additionally, such features as multiple thermoclines, inversions, and thermal transients are identified also and their key points are included in the informational data printout.

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TABLE OF CONTENTS

Page

List of Figures 5

List of Symbols 7

1. Introduction 9

2. Method of Analysis 12

   A. Primary Features 13
   B. Secondary Features 13
      1. Transients 13
      2. Multiple thermoclines 14
      3. Inversions 14
   C. The Gaussian Thermocline 15
   D. The non-Gaussian Thermocline 19
   E. Irregular Thermal Features 20
      1. Transients 20
      2. Multiple thermoclines 23
      3. Inversions 24

3. Example of Input 28

   A. Data Deck Input 28
   B. Magnetic Tape Input 31

4. Computer Program Operation 33

5. Output from Computer 36

6. Discussion and Conclusions concerning the results 45

7. Recommendations 48

Bibliography 50

Appendices 52

I. Flow Chart 53

II. Objective Thermocline Analysis Program 84

III. Write-up of "DRAW" subroutine 118

IV. "BCD" Conversion Program 122

LIST OF ILLUSTRATIONS

Figure		Page
1.	Gaussian thermocline and its frequency function	16
2.	A non-Gaussian thermocline	21
3.	Normal and expanded scale transient	22
4.	Triple thermocline	25
5.	Typical BT trace with an inversion	26
6.	Data deck assembly and card format	29
7.	Hand drawn thermal curve (after Tully 1963)	37
8.	Example of output for real data curve	38
9.	Typical inversion (from Boston 1966)	39
10.	Example of output from inversion	40
11.	Hand drawn bathythermogram	41
12.	Example of output for multiple thermoclines	42
13.	Computer trace	43

LIST OF SYMBOLS

e	2.718281
m	Median of a Gaussian thermal distribution
n	Any positive integer
T	Temperature (degrees Celcius or Farenheit)
T_{bt}	Temperature at the bottom of the thermocline
T_B	Lowest temperature read off bathythermograph trace
$T(0)$	Temperature at sea surface
T_1	First temperature read off bathythermograph trace
T_n	nth temperature read off bathythermograph trace
$T(-\infty)$	Temperature at the base of the lower isothermal layer
T_t	Temperature of the mixed (upper isothermal) layer
$T(Z)$	Temperature as a function of depth
T_{min}	Minimum temperature in inversion
Z	Depth (feet or meters corresponding to units of T)
Z_b	Depth of the mixed (upper isothermal) layer
Z_c	Depth of the center of the thermocline
Z_{c1}	Depth of the center of the first thermocline when multiple thermoclines exist
Z_{c2}	Depth of the center of the second thermocline when multiple thermoclines exist
Z_t	Depth of the mixed (upper isothermal) layer and equal to Z_b
$Z(T_n)$	Depth at which temperature T_n is found
$Z(T_n)_i$	equals $1/2[Z(T_n) + Z(T_{n+1})]$

$Z(T_n)_i^2$	equals $[Z(T_n)_i]\cdot[Z(T_n)_i]$
$Z_j(T_n)$	double notation used when more than one depth has the same temperature; the j refers to the order in which the depths are encountered from the surface to the last temperature read
ZUPP	Depth of the upper boundary of an inversion
TUPP	Thermal magnitude of an inversion
$\Delta Z(T_n)$	equals $Z(T_{n+1}) - Z(T_n)$
$\Delta^2 Z(T_n)$	equals $\Delta Z(T_{n+1}) - \Delta Z(T_n)$
π	3.14159...
σ	Standard deviation
$\sum$	Summation operator

1. Introduction.

Since the introduction of the bathythermograph by Rossby and Montgomery (1934), and its further modification and perfection by Spilhaus (1938), there has been almost continuous thermal structure information funneled into the various collection agencies which has been handled manually under procedures outlined by LaFond (1951). This data collection has resulted in vast numbers of bathythermograph slides that have been noted, and then stored away for future analysis. In more recent years bathythermograph data has been stored on aperture cards, using techniques similar to those suggested by Sauer (1964). The Canadian Oceanographic Data Center, Scripps Institution of Oceanography, and the Fleet Numerical Weather Central, Monterey, California, have further modified this procedure by a method similar to that suggested by Sauer and Hope (1967), where a device has been invented which will take incoming bathythermograph slides and convert them directly to digitized data format. This system described by Sauer and Hope (1967) consists of taking the grid/slide combination and transferring it to an aperture card by means of the BT Processor, a modified 3M Processor Camera. It has the advantage of preserving the original analog trace. The aperture card is then fed through a hopper device directly into a Caps Jeffreé projector with a D-MAC curve-follower unit. The time required for this unit to process one bathythermogram trace is approximately 45 seconds with a claimed accuracy of 1.0% of the full depth range and 0.1 degrees Farenheit. After exhaustive testing at the Naval Hydrographic Office as described by Stewart (1963) Sauer and Hope (1967) of the Canadian Oceanographic Data Center felt this degree of reliability in fact was not approachable. Accordingly, they converted their system to record temperature to a minimum of every 0.1 degrees Celcius and to the nearest whole meter.

Papers by Tully (1961, 1964) show that there are certain features which must be identified in order to classify a bathythermograph trace. Tully states that these few parameters can be used to identify the thermal structure in any area of the ocean. Among these features is a potentially isothermal layer, which may or may not contain transients. There is a seasonal thermocline, in which the gradients may be regular or irregular. Below this layer is a sub-thermocline layer in which the gradients are less than in the thermocline. Superimposed on these features are various types of short term fluctuations which possess varying degrees of significance, such as temperature inversions.

Tully (1964) suggests in this same paper that the thermal structure can be defined by the following features:

(1) Surface Temperature.

(2) Potential Layer Depth. This figure includes the average depth to the top of the thermocline, plus any modifications due to internal waves, etc.

(3) Depth to the Bottom of the Thermocline. In many oceanic areas this depth has an associated distinct temperature minimum and therefore is very definitive. In areas like the tropics it is usually not a significant feature.

(4) Thermal Magnitude of Thermocline. To researchers this may be a very significant feature, because it can signify a boundary to restrict fish movement, water mass mixing, etc.

(5) Other Less Definable Features. There are other parameters that may be considered, like the location of temperature minimum in a thermal inversion, mixed layer depth, etc. These features cannot be

fitted easily into a generalized machine processing format for ready identification. They are not common features, and may have special variables that depend solely upon the area of the ocean being investigated, or upon the season of the year.

As Boston (1966) states, "until the information on bathythermograph slides can be conveniently analyzed by machine, much information about the thermal structure of the upper layers of the ocean is quite likely to remain hidden in an ever growing mountain of smoked and/or gold film glass slides, photographs of same, or punched cards." Two distinct problems arise: (1) the digitizing of the bathythermograph data to a form that can be processed by high-speed computers and data handling systems; and (2) specification of a program that will take this digitized data and process it for use in oceanographic research; the program needs the generality to be able to handle any shape trace, and flexibility so that further routines may be added or subtracted at will without destroying the basic integrity of the program. As we have seen, some progress is being made in the handling of the first problem.

The second problem is the topic of this thesis; the objective analysis of digitized bathythermogram traces. The standard features as suggested by Tully (1964) are identified and printed out in a concise informative way. One or two additional features, like the identification of thermal inversions and transients, are included in an attempt to show that further features may be added to this program according to the requirements of the individual user.

2. Method of Analysis of Thermal Structure.

There will be two separate analytical methods developed for handling the objective analysis of the thermal structure. In his technical paper, Boston (1966) suggested the following two methods, on which this thesis is based. One method consists of a Gaussian temperature structure being assumed for the thermal parameter discussed. The second method is a common finite difference method, utilized to find inflection points in the various trace slopes.

A prerequisite to both methods is that the data from the original analog bathythermograph trace be reduced to an ordered set of depths read at some predetermined temperature interval. From this ordered set, the thermal structure can be defined objectively in terms of certain primary and secondary features. Both methods require only the first and second finite differences with depth; therefore only data from depths corresponding to some constant thermal interval (conveniently 0.5 to 1.0 degrees) are required to handle the analytical technique. However, it is convenient to include temperature data corresponding to these points, as in the computer output there are locations where information as to the thermal magnitudes are as important as the spacial magnitudes.

Thermal structure, as defined in this thesis, is the relationship of the temperature, T, to depth, Z, as a function of time and position. Furthering earlier ideas, Tully (1964), Tully and Giovando (1963), and Uda (1963) show in their papers that the thermal structure changes with season, latitude, and even oceanic region. However, Tully (1964) also suggested that the number of different features for a given application is small. Section A considers those features common to most oceanic regions within the upper 300-400 meters of the ocean. Section B considers those features that are of major concern in such fields as antisubmarine warfare, biological forecasting, and fisheries that are not discussed or included in Section A.

A. Primary Features:

The primary features as suggested by Tully (1964) and Boston (1966) consist of several convenient parameters; (1) surface temperature, (2) depth of potential layer depth (upper isothermal), (3) depth of the bottom of the thermocline, and (4) magnitude of the thermocline.

The potential mixed layer is that as defined by H. O. Pub SP-105, Vol 5, and is considered to be isothermal, although this "isothermal" region accepts small positive or negative gradients up to 0.3 degrees Farenheit per hundred feet. The termination of this nearly-isothermal layer is usually abrupt enough to clearly mark the region where the thermocline or other feature takes place. The depth of the mixed layer will be defined as Z_t the top of the thermocline. Likewise, Z_{bt} the base of the thermocline, can be considered the top of the lower nearly-isothermal area.

Once the top and bottom of the thermocline have been defined, with T_t as the temperature at Z_t, and T_{bt} as the temperature at Z_{bt}, the definition of the magnitude of the thermocline is

$$\Delta T = T_t - T_{bt} \tag{1}$$

B. Secondary Features

The secondary features are usually considered as time varitions in the primary features of Section A, and can occur at any point in the vertical water column being considered.

1. Transients

The term transient will be defined here as referring to short term fluctuations of the thermal structure. It is usually the result of wind mixing, and vanishes over a period of a day or more. The program produced for this thesis will recognize these transients, assuming that these thermal transients take the usual form of small but sharp gradients that appear as irregularities on the main thermal structure. Transients are often found in association with the well known "afternoon effect." This program will aid in the verification of the prediction methods outlined by Tabata and Giovando (1962).

2. Multiple Thermoclines

Heating and wind mixing conditions can also produce more than one stable thermocline. The growth of two stable thermoclines has been well documented by Tully and Giovando (1963). The occurrence of these multiple thermoclines is sufficiently common and vital to underwater acoustic prediction systems that they merit identification.

3. Inversions

Inversions are a common oceanic feature, an example of which has been described by Roden (1964), and must be identified if one is to accurately predict underwater sound transmission. The thermal inversion takes form when the temperature below the main thermocline (below Z_{bt}) decreases with depth to a minimum, then increases markedly, and finally decreases again, but now usually at a more reduced rate than the first decrease. These thermal features are of extreme interest in underwater communications as the point of minimum temperature in this thermal structure forms the axis of a "sound channel" formed by the thermal bending of acoustic rays by this inversion.

The following methods will be used to identify these primary and secondary features within the computer program designed for this thesis.

C. The Gaussian Thermocline

A gaussian, or normal, distribution (see Figure 1) of temperature, T, as a function of depth, Z, is given by

$$T(Z) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{Z} e^{(-1/2)Z^2} \, dZ \qquad (2)$$

whose corresponding frequency function is

$$\frac{dT(Z)}{dZ} = \frac{1}{\sqrt{2\pi}} e^{(-1/2)Z^2} \qquad (3)$$

If the distribution function is $T\left(\frac{Z-m}{\sigma}\right)$, where σ greater than 0 and m are constants, then the frequency function becomes

$$\frac{dT(Z)}{dZ} = \frac{1}{\sigma\sqrt{2\pi}} e^{\frac{-(Z-m)^2}{2\sigma^2}} \qquad (4)$$

The function described by (4) has the following characteristics:

(a) it is symmetric about $Z = m$,

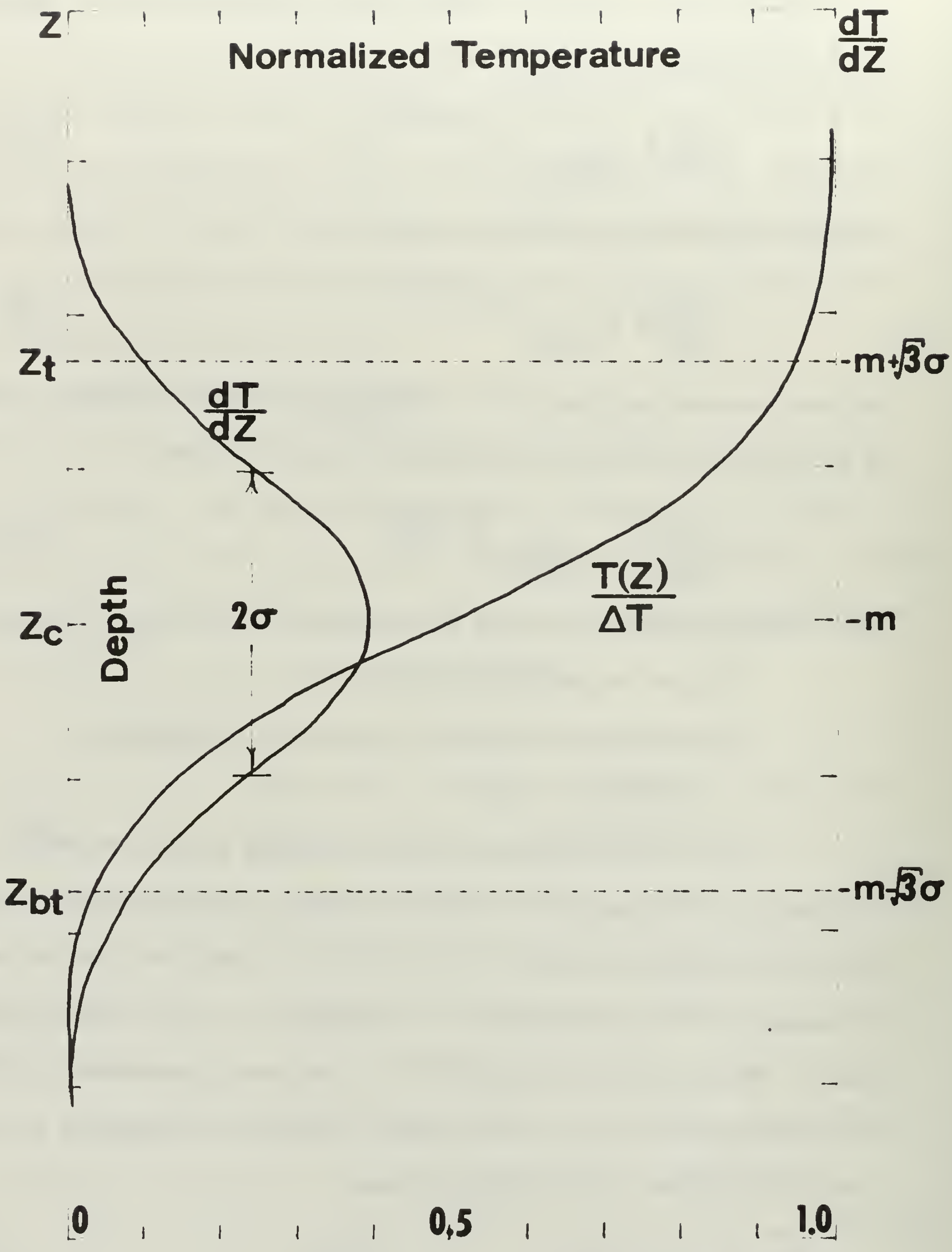
(b) it has two symmetric points of inflection at $Z = m \pm \sigma$, and

(c) it has a maximum rate of change at $Z = m \pm \sigma\sqrt{3}$

A change in the numerical value of m causes a displacement of the curve in the vertical direction, Z, but does not alter the form of the curve. A change in σ has the effect of altering the scale of both coordinate axes. The smaller the value of σ, the more concentrated the curve is about the point $Z = m$. If the water surface is defined as $Z = 0$, and the depth considered to be infinite, then

$$T\left(\frac{Z-m}{\sigma}\right) = \frac{1}{\sigma\sqrt{2\pi}} \int_{-\infty}^{0} e^{\frac{-(Z-m)^2}{2\sigma^2}} \, dZ \qquad (5)$$

is the function defining the vertical temperature distribution. The center of the thermocline, or the center of the curve of the $T\left(\frac{Z-m}{\sigma}\right)$ distribution, is at



(after Boston 1966)

Fig. 1 Gaussian thermocline and its frequency function (first derivative)

$$Z = Z_c = -m \qquad (6)$$

The top and bottom of the thermocline are then defined as being located at the points of the maximum rate of change of slope of the $T\left(\frac{Z-m}{\sigma}\right)$ curve; namely,

$$Z_t = -m + \sigma\sqrt{3} \qquad (7)$$

$$Z_{bt} = -m - \sigma\sqrt{3} \qquad (8)$$

which are illustrated in Figure 1.

The handling of bathythermograph data leading to the application of results (6), (7), and (8) is very simple, since values of m and σ may be computed directly from the (t,Z) distribution curve. Consider the first two moments of the (T,Z) curve about the origin, Z=0, whereby the (nth) moment of the curve about the origin is meant the mean values of Z^n defined as $\overline{Z}^n$, where n is a positive integer. Then with the normal curve, the first moment is identical with the center of the thermocline:

$$Z_c = \frac{1}{T(0)-T(-\infty)}\int_{T(-\infty)}^{T(0)} Z(T)\,dT \qquad (9)$$

where T(0) is the temperature at the surface Z = 0 and T $(-\infty)$ is the temperature at the bottom of the lower isothermal layer which, in this idealized case, is assumed to extend to the bottom of the ocean. The second moment

$$\overline{Z}^2 = \frac{1}{T(0)-T(-\infty)}\int_{T(-\infty)}^{T(0)} Z^2\,dT \qquad (10)$$

can be used to compute σ , since the variance, σ^2, is given by

$$\sigma^2 = \overline{Z}^2 - m^2 = \overline{Z}^2 - Z_c^{\,2} \qquad (11)$$

In practice, several simplifications are possible. The temperature T $(-\infty)$ is measured at the bottom of the bathythermograph cast. The differentials, dT, become finite differences, ΔT, and the integrals are replaced by summations. If the depths of the temperatures are read at one degree intervals, for example, then the T's can be replaced by unity.

One must remember that although integration is a continuous process, the less accurate summation over finite intervals is not. The larger the interval, the less accurate is the summation. The working value of sigma, as computed by the routine, cannot exactly equal the correct value obtained from integration over the normal curve. Thus equations (7) and (8) must be modified by some weighing factor depending upon the temperature interval chosen. Allowing this factor to be defined as, sk, equations (7) and (8) become

$$Z_t = -m + sk\sqrt{\sigma} \tag{7A}$$

$$Z_{bt} = -m - sk\sqrt{\sigma} \tag{8A}$$

where a temperature interval of 0.5 degrees gives sk equal to 1.47 and a temperature interval equal to 1.0 degrees gives a value for sk equal to 1.30.

In summary, the objective definition of the top, bottom and center of a Gaussian thermocline requires only readings of (a) surface temperature, (b) bottom temperature, and (c) depths at some constant pre-chosen temperature interval.

The center of the Gaussian thermocline is

$$Z_c = \overline{Z(T_n)_i} = \frac{1}{T_1 - T_{bt}} \sum Z(T_n)_i \tag{12}$$

Since

$$Z(T_n)_i = \frac{1}{T_1 - T_{bt}} \sum Z(T_n)_i^2 \qquad (13)$$

Then

$$\sigma^2 = \overline{Z(T_n)_i^2} - Z_c^2 \qquad (14)$$

The top and bottom of the Gaussian thermocline readily follow from (7A) and (8A).

One problem remains: the decision as to whether or not a normal distribution exists; lacking this distribution, the inaccuracies built into this process are not tolerable. This determination can be accomplished by computation of the third moment. However, in the following section it is apparent that this computation is not necessary.

D. The non-gaussian Thermocline

The analysis of the more common type of thermal structure, the non-gaussian thermocline, requires the computation of finite differences on Z(Tn). The first finite difference will be defined as

$$\Delta Z(T_n) = Z(T_{n+1}) - Z(T_n) \qquad (15)$$

and the second finite difference as

$$\Delta^2 Z(T_n) = \Delta Z(T_{n+1}) - \Delta Z(T_n) \qquad (16)$$

Generally, the first finite difference is always positive. The second finite difference will be negative until, in this case, the point of inflection of the (T,Z) distribution curve is reached, at which point $\Delta Z(T_n)$ becomes non-negative. If the first non-negative second finite difference is $\Delta Z(T_n)$, then the center of the thermocline is $Z(T_{n+1})$.

In order to locate Z_t, only the upper portion of the (T,Z) distribution curve is considered, where a $(Z \leq Z_c)$ synthetic lower portion to this curve segment is constructed so that together with the upper real segment a normal distribution is formed. From this curve, σ is computed by methods described in the previous section and Z_t is given by formula (7A). (see Figure 2b).

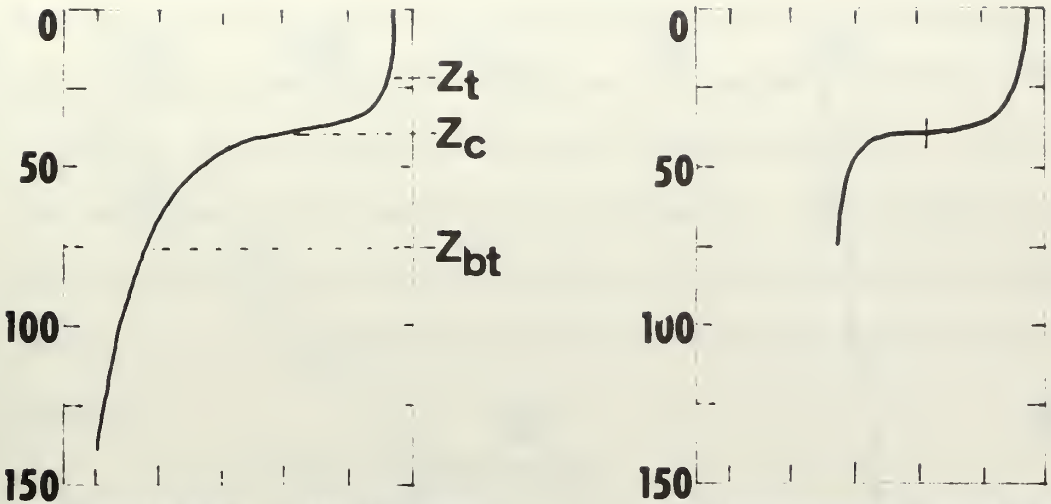
Similarly, only the lower $(Z \geq Z_c)$ part of the (T,Z) distribution curve is utilized in computing Z_{bt}. An upper portion of the curve is added to the segment and a new value of σ is computed. Z_{bt} is then calculated by using formula (8A). (See Figure 2c).

E. Irregular Thermal Features.

1. Transients

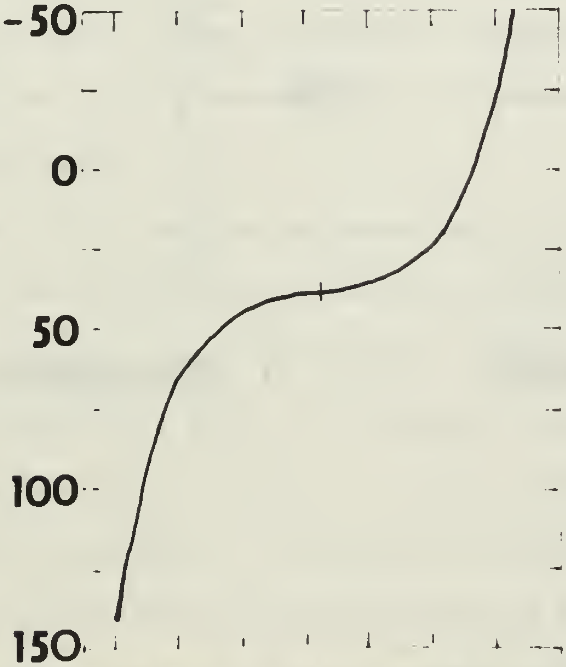
Transients, according to Boston (1966), are usually considered to be less than one degree in magnitude and might not be seen by a greater thermal interval. Thus, it is necessary to have a small grid spacing, say 0.1 degrees, to identify these transients. Spilhaus (1938) relates that the bathythermograph is seldom more accurate than 0.5 degrees, borne out by the testing of Stewart (1963), due to such problems as dull stylus, hysteresis, and calibration. Even if the instrument were exact, and hysteresis were not present, the thickness of the trace limits reading accuracy to about 0.2 degrees. Hence, although the grid spacing chosen for this program is unrealistic at 0.1 degrees, it is retained with the possibility of more accurate thermal instruments, or more accurate bathythermograph readings, in the future.

If such accuracy were possible (see Figure 3) transients could be identified by simply identifying the sign changes of $\Delta Z(T_n)$. If the



a. Complete non-Gauss. thermocline

b. Segments used to compute Z_t



c. Segments used to compute Z_{bt}

Fig.2 A non-Gaussian thermocline

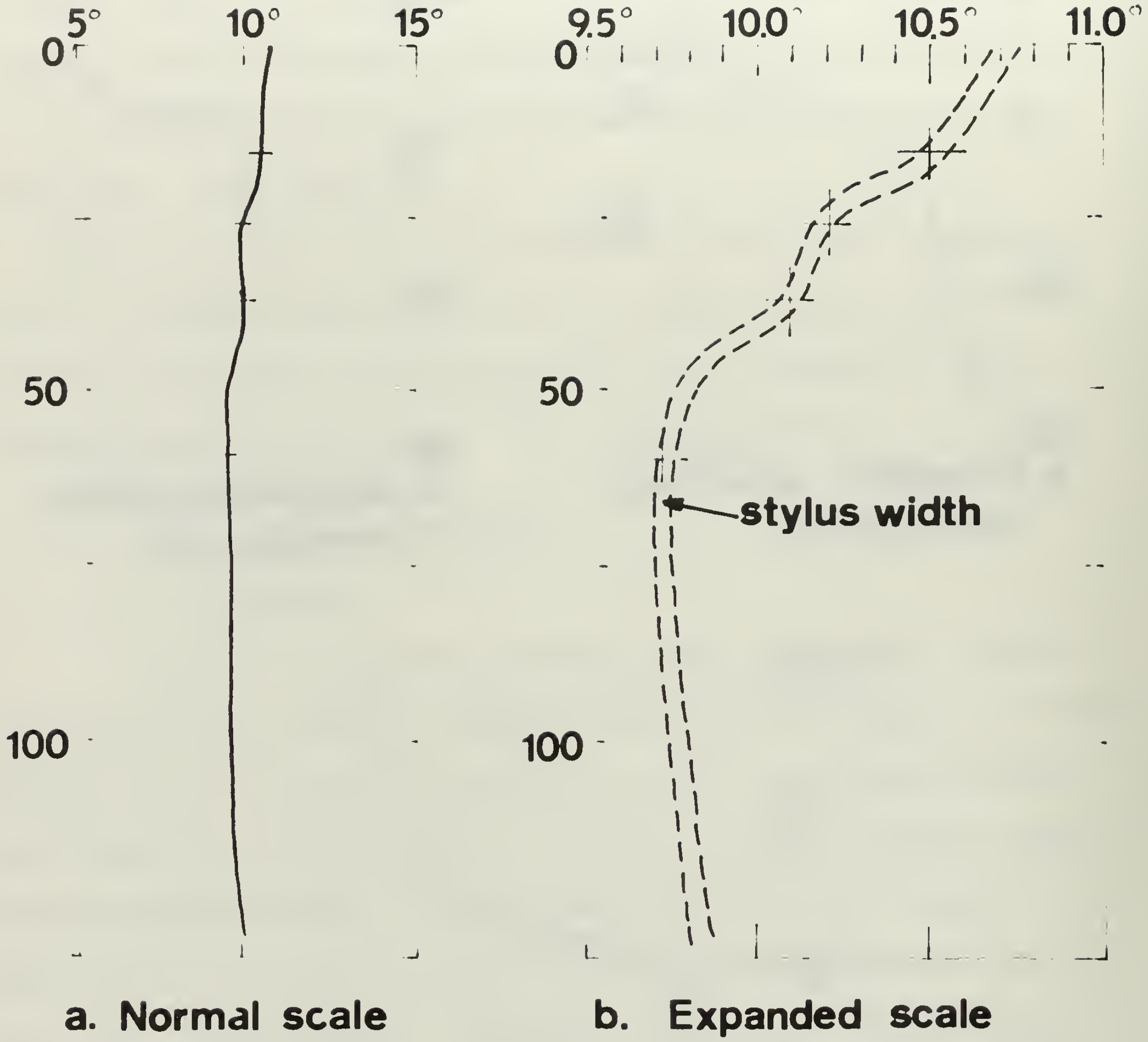


Fig. 3 Normal and expanded scale transient

first negative value encountered was $\Delta Z(T_n)$ then the beginning of the first transient would be at $Z(T_{n+1})$. Then the end of the first thermal transient and the beginning of the second transient is signified by a sign change of $\Delta Z(T_n)$ from positive to negative. If this occurs at $\Delta Z(T_n)$ then the end of the first transient occurs at $Z(T_n)$ and the beginning of the next occurs at $Z(T_{n+1})$. This process will continue until the top of the first major thermocline is encountered; generally we are interested in only the transients in the upper isothermal region.

2. Multiple thermoclines

The analysis of a thermal distribution containing more than one major thermocline proceeds along the lines just discussed in the previous section on transients. In Boston's article (1966) he states that a grid spacing of one degree is generally adequate if there are only two thermoclines, and a grid spacing of 0.5 is necessary should there be more thermoclines present.

As in the transient analysis the sign changes of $\Delta Z(T_n)$ are examined. If the first positive value is $\Delta Z(T_n)$ then the center of the first thermocline would be located at $Z(T_{n+1}) = Z_{c1}$. The center of the second thermocline, Z_{c2}, is indicated when the sign of $\Delta Z(T_n)$ changes from negative to positive. If this occurs at $\Delta Z(T_n)$, then, as in the first thermocline, the center is located at $Z(T_{n+1}) = Z_{c2}$. The centers of all subsequent thermoclines are found by continuing this process throughout the length of the trace.

When the centers of the shallowest and deepest thermoclines have been identified, the method outlined in Section D, the non-gaussian thermocline will be used to determine the top of the shallowest thermocline and the bottom of the deepest thermocline. Then considering the fact that $\Delta Z(T_n)$

is a measure of the slope of the (T,Z) curve, the maxima in $\Delta Z(T_n)$ corresponds to the most nearly isothermal conditions. Thus these maxima can be used to separate the thermoclines. Once this seperation has been accomplished, the procedure from Section D can be used again to locate the top, bottom, and center of each individual thermocline. Considering the fact that the thermal structure is assumed to be continuous, with only small spacing between consecutive thermoclines, there is little need in making the identification any more accurate, or finer, than the subdivisions that are indicated by the maxima. Figure 4 shows an example of real traces in the ocean with this multiple thermocline feature.

3. Inversions

Large inversions (± 0.5 degrees Celcius) are usually found where water sources of different origin are close together or where strong velocity shears are encountered. Tully and Giovando (1963) document this feature. Uda (1963) and Tully and Dodimead (1963) also show that in regions such as the subarctic, where there is excess precipitation, the summer profile may be characterized by a nearly permanent summer inversion located at about 100 meters depth.

The main feature (see Figure 5) of an inversion is the sign change of the slope of the (T,Z) distribution curve. The major points of interest to the investigator are usually considered to be:

(a) upper and lower boundries denoted by Z_{c1} and Z_{c2} respectively,

(b) magnitude of the inversion, ZUPP and TUPP, being the spacial and thermal magnitudes, respectively,

(c) minimum temperature, TMIN,

(d) depth of minimum temperature (depth of axis of sound channel), ZMIN.

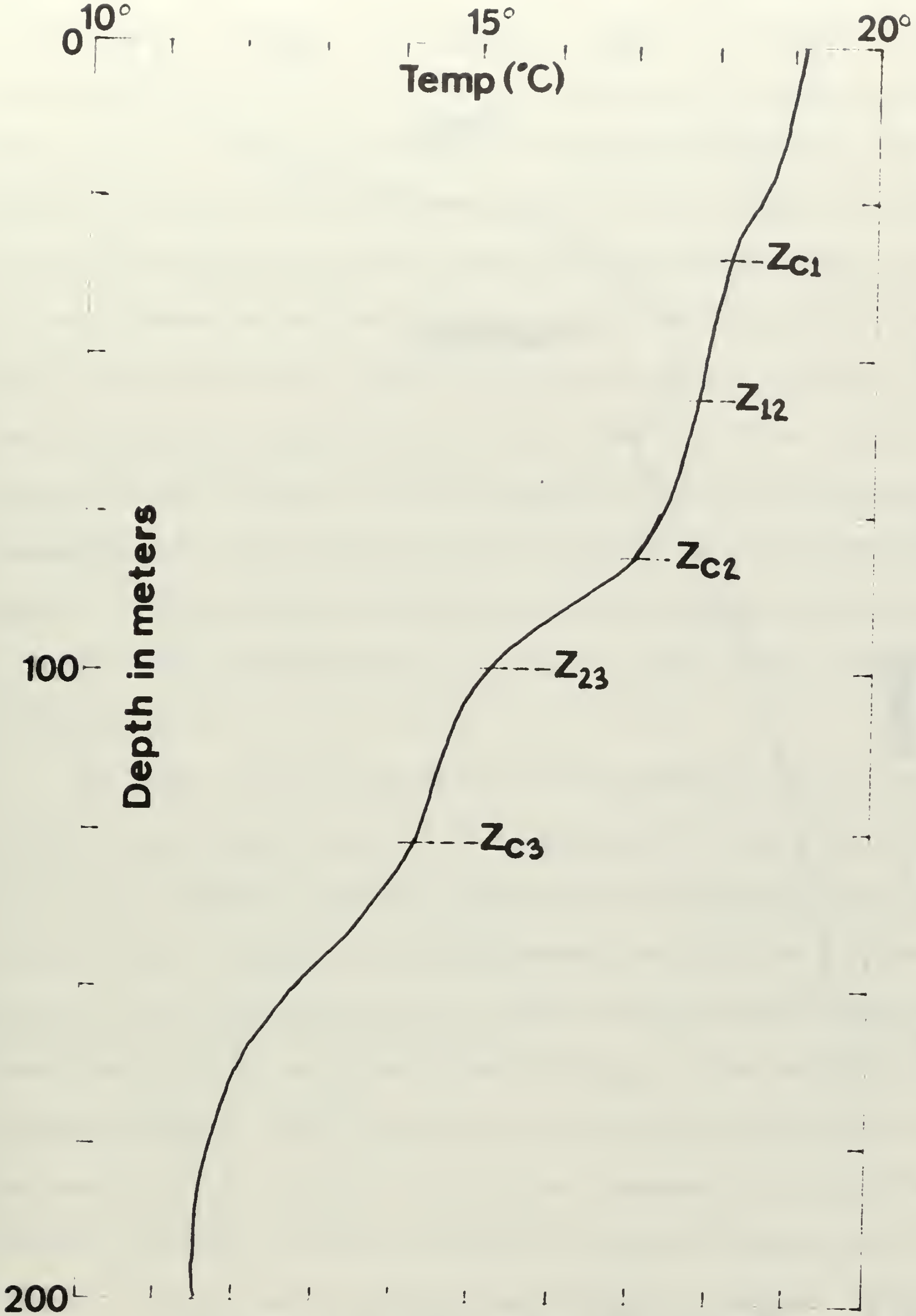


Fig. 4 Triple thermocline - Monterey Bay (April, 1968)

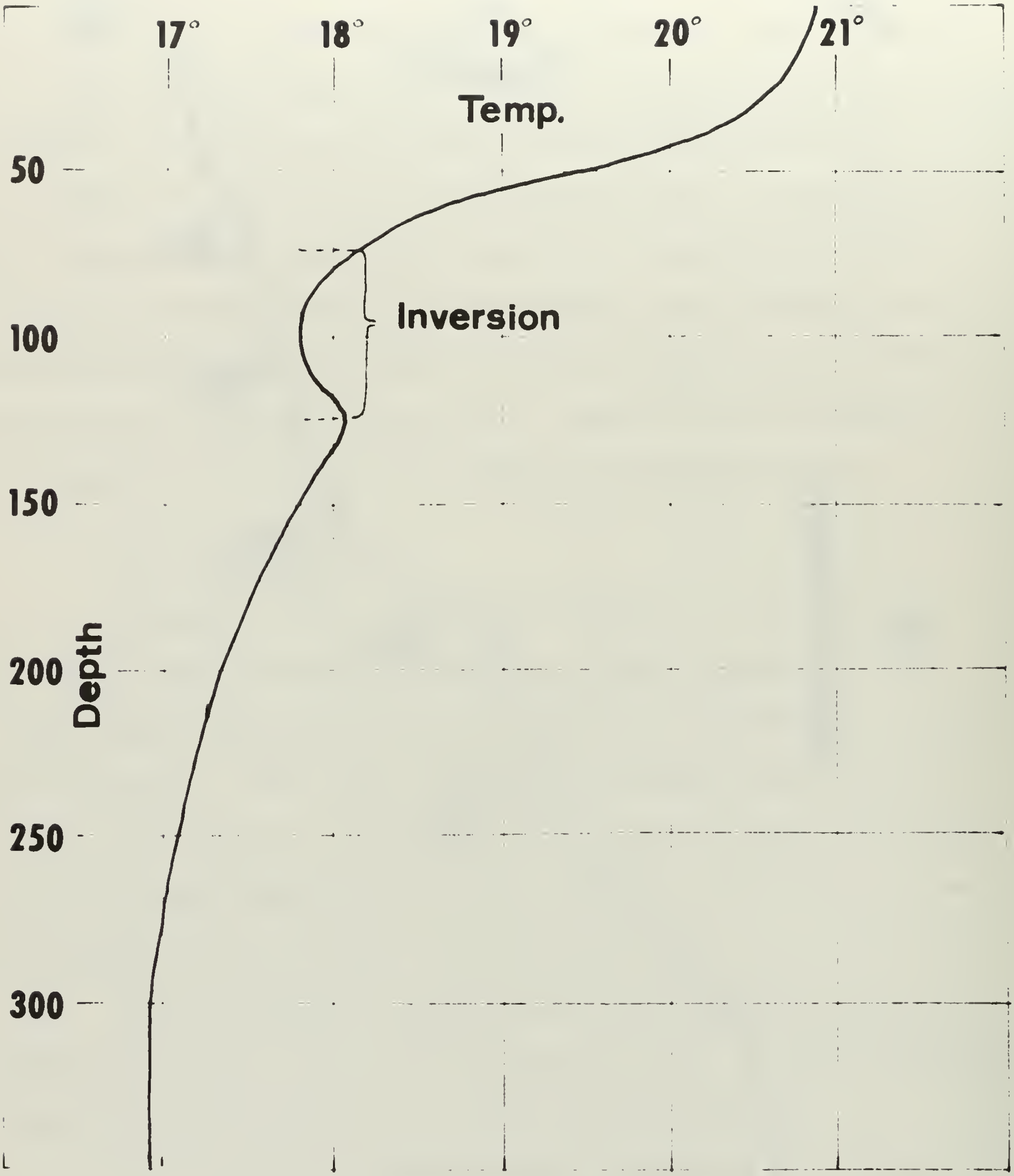


Fig. 5 Typical BT trace with an Inversion

Referring to Figure 5, it should be noted that this system of analysis will require a more elaborate notation system, since the curve is no longer single valued (that is, more than one depth, Z_n, will have a specified temperature). In order to distinguish between these depths the notation $Z_j(T_n)$ will be introduced where the subscript j refers to the order in which a multiple occurrence happens from the surface down. Thus, if Tn occurs at three depths, the shallowest depth would be indicated as $Z_1(T_n)$, the intermediate depth $Z_2(T_n)$, and the deepest as $Z_3(T_n)$. As the trace is read vertically from the surface down, the trace appears to be single-valued (one depth has one temperature), then double-valued (one temperature at three depths), before returning to a single-valued state again. Since the finite differences must be computed, its first and second finite differences will be defined as $\Delta Z_j(T_n)$ and $\Delta^2 Z_j(T_n)$, respectively.

The upper and lower boundaries of the inversion occur at the first double-valued temperature. If this temperature is Tn, then $Z_{c1} = Z_1(T_n)$ and $Z_{c2} = Z_2(T_n)$. The last double-valued temperature, or a lower-valued single temperature included between the last double-valued temperatures, is the minimum temperature, TMIN, and the depth of this minimum temperature, ZMIN, is defined from $Z_1(T_{min})$. The magnitude of the thermal inversion, TUPP, is given by the absolute value of the difference between the first and last double-valued temperatures. Once these inversion features have been identified, pertinent features above and below the inversion still must be identified by the methods outlined in Section D.

3. Example of Input

Two methods of input to this program are data deck and tape deck. These two examples illustrate these methods.

A. Data Deck Input

In using a data deck input, where an analyzer does not have access to the digitizing machines and must key-punch his data deck, it is possible to input both positional and curve data. The data deck must be made up as follows (see Figure 6);

(1) The data must be printed from the bathythermograph curve, at some pre-chosen thermal interval, i.e., - 0.5 degrees. The data are punched on the data aperture cards by punching the temperature, followed by its depth as picked off at the chosen delta-T. Each data bit is allowed ten spaces on the aperture card and no other data can be included in this ten space unit, so that a maximum of four data sets can be punched per data card, (since there are only 80 spaces allowed per card). The thermal data is continued through as many aperture cards as necessary to insure complete recording of the entire trace.

(2) Immediately following the completion of the first trace, the operator must insert "Control Card 1", which is a dummy control card consisting of "0.0" substituted for the temperature, T, and any "non-zero" value substituted for the depth, Z. This dummy card signals the main program that the reading routine has completed reading the data trace and is ready to read the positional data, if it exists, or proceed on with the analysis of the trace.

(3) Following "Control Card 1" we insert the positional data card, if we desire to read in this information. This card contains the geographical position, both latitude and longitude to the nearest

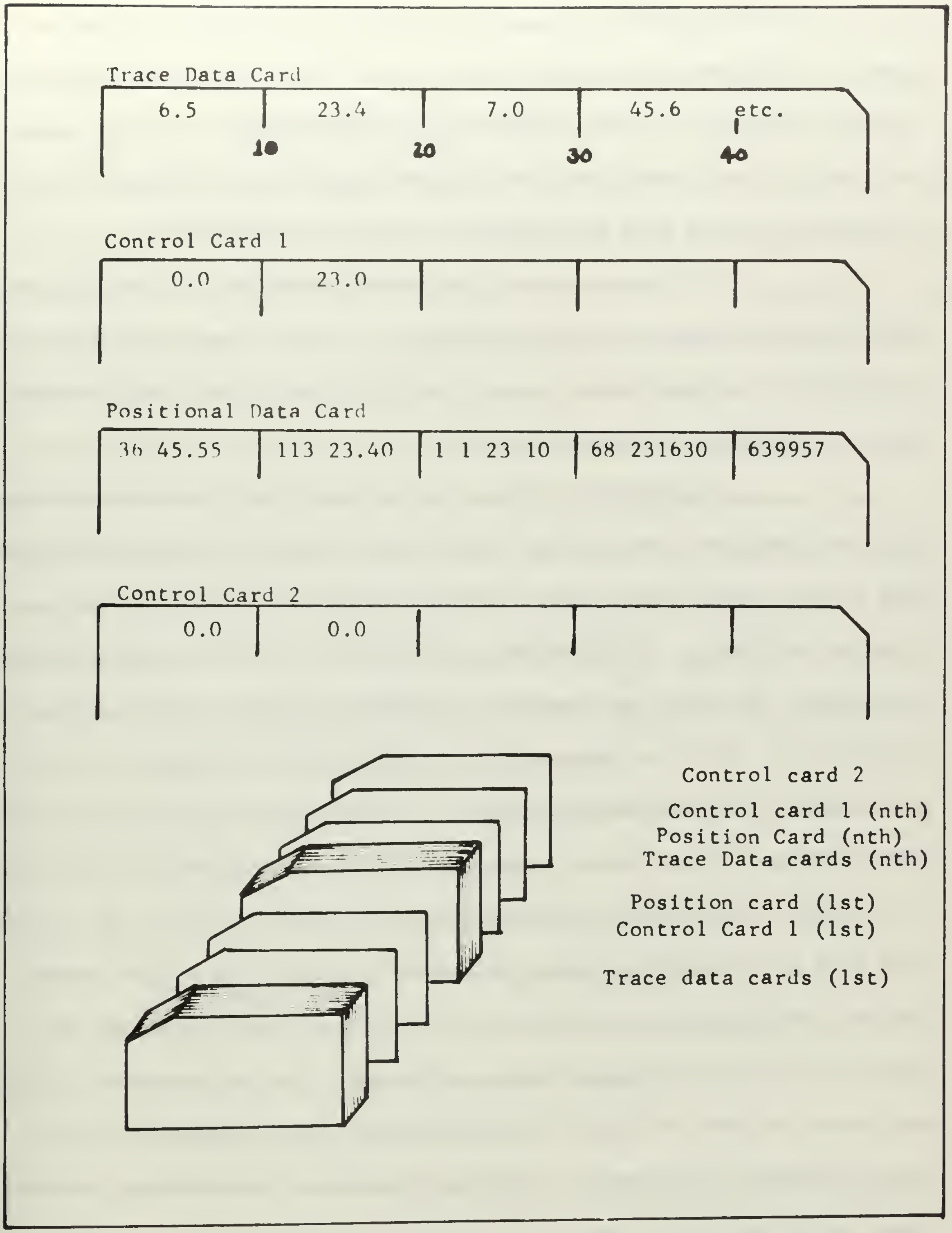


Fig.6 Card Format and Data Deck Assembly

hundredth of a minute, the local date, the Greenwhich Mean Time and date of the bathythermograph cast, and the serial number of the bathythermograph. If the positional data card is used, then every position must be filled in exactly as noted in Figure 6 and Appendix II. If the necessary data is not known, then the unknown spaces must be filled with "0"'s. The format on this card is absolutely vital and inflexible.

(4) Next we repeat the above procedures (1) through (3) for each bathythermograph trace desired. It is not necessary to insert a positional card with each trace, but if the positional card is used it must be complete, as mentioned above.

(5) When the entire data package has been made up of trace data and positional data cards, then "Control Card 2" is inserted as the last card to signal the program that the data is finished and the program can terminate. "Control Card 2" consists of a normal data card format, except the "0.0" is inserted in position for both temperature, T, and depth, Z. This is always the last card in the data deck (if we do not consider the programming control cards used by the system), and will always follow the positional data card for the last trace or if this data is not used, then it will follow the last "Control Card 1." The entire data deck is assembled as shown in Figure 6, and may be of any length. The only programming prerequisites are that the thermal inverval be a constant for each individual trace, although it is not necessary for all the traces to have the same interval, and the input format, Figure 6, must be followed rigorously. All other necessary computations, such as sigma, weighing factor, etc., are contained or computed within the program.

B. Magnetic Tape Data

When the input data can be digitized, by such facilities as the Fleet Numerical Weather Central, Monterey, or the Canadian Oceanographic Data Center, a few modifications must be made to the basic program reading methods as they presently exist in Appendix II. In order to use magnetic tape input it is necessary to remove the cards that are serialized (right hand margin) 0185 - 0204 and insert in their place new cards designed to read the magnetic tape. It is important to note here that the format of the tapes and even the type of tapes makes a vast difference in the make up of the reading cards and great care must be used in inserting the correct control and reading cards in order to insure not shutting down the computer. Before using tapes, be sure to check the individual instruction manual and the individual tape specifications and rigorously follow the instructions on the format for the make up of these new cards to be inserted. The following information must be considered in each case:

(a) whether seven or nine track tape,
(b) data density,
(c) whether even or odd parity,
(d) whether the data are translated or not,
(e) if translated, what machine language,
(f) record length,
(g) whether or not the data are blocked,
(h) if blocked, what size.

All this information is vital in making up the correct system control cards for the tape reading unit. Once the system control cards are correctly made up and inserted around the program, then a normal "read" card, for example;

```
          READ(8,1,END=60)
    1     FORMAT(8A5)
```

is used, where, in this example, we are reading on tape reader "8", sixty traces consisting of eight data sets per trace.

4. Computer Program Operation.

The computer first reads in the data for an individual trace, as outlined in Section 3, and then reads in the positional data (if existent in data deck). Once the individual trace is read into the program, the computer takes over, using the analysis method programmed by this routine to start the investigations for the features outlined in Section 2. Before starting any further investigations the program looks at the thermal interval and choses one of three possible values for the weighing factor, SK. This value is then carried throughout the calculations for this trace. If the positional data is included, the first output is a formalized printout of this informational heading. Once this has been executed, the main program starts a searching routine to identify various possible features before calling the specific sub-routines necessary to analyze this data. The program first looks for double-valued temperatures in the vertical dimension. If these double-values exist the program calls the inversion subroutine, INVERS, to calculate the top and bottom of the inversion and its spacial and thermal magnitude. This subroutine first calls a specialized subroutine, ORDER1, that takes all the input data from that trace and checks to insure that the data is in correct order from the surface down (consecutive readings) and if it is not, reorders the data in the correct sequence. Once the data is in correct order, then the program does a quick safety check to insure that it does not have a non-inversion, (where the temperatures first increases with depth and then decreases, giving not an inversion, but a positive surface gradient followed by the normal main thermocline, a feature that the main program might identify as an inversion). If this condition does exist, the subroutine terminates and returns the flow to the main program for further investigations. If an inversion exists ,then, by the use of do-loops, INVERS calculates the top, bottom, and magnitudes of the inversion as outlined in Section E.3. Once the data has been analyzed and these results are available, the subroutine then calls four specialized printing subroutines, PRINT3 through PRINT6, to print out the data in a useful format. INVERS then returns the order flow to the MAIN program for further investigations.

The MAIN program then investigates the thermal interval, delta-T, to insure that if the interval is less than 0.2 degrees a thorough investigation for the presence of transients is accomplished. If the interval is 0.2 or less, the MAIN routine calls the transient investigation routine, TRANS, which proceeds to analyze for the presence of transients as outlined in E.1. Upon completing the analysis, the results are printed out, if any exist, and the flow returns to the MAIN routine.

Once returned to the MAIN program, the final investigation is made into the possibility of multiple thermoclines. The MAIN program calls the multiple thermocline subroutine, MANYT, which utilizes analysis procedures outlined in Section E.2. Within this subroutine is the provision to go to another subroutine, NONGA, designed to handle the more specific case, should only a single main thermocline exist. The NONGA subroutine uses the procedure outlined in Section D to find the top, center, and bottom of the thermocline. In both subroutines, looking at thermoclines, the results are printed out by utilizing the specialized printing subroutines, PRINT1 and PRINT2.

A flow chart (simplified) for the entire process is shown in Appendix I, and the entire program can be inspected by referring to Appendix II. It is worthy of note, that this program will not identify all three features, transients, multiple (or single) thermoclines, and inversions, in a single trace as the existance of all three would be very rare. However, the program will look for transients in the upper near-isothermal layer and then investigate the possibility of an inversion below this area, or if the inversion does not exist then look at the thermocline(s) in the region below the near isothermal layer.

Also, as an additional feature the program can be called to print out a graphic display of the input data (Appendix III), thus giving a visual representation of the data that is printed out on the output data sheets. This auxiliary feature can be called by inserting the following cards in the MAIN program immediately following the card serialized 0199.

```
CALL SEE13(T,Z,ICOUNT)
```

which will call the SEE13 subroutine that utilizes the library program, "DRAW", to give graphic display of the input data set and fits a curve to these points. Before using this call, the user must exercise care and carefully read the rules for usage of "DRAW" in subroutine "SEE13" as are outlined in Appendix III.

Another feature included as part of this thesis package, is a provisional set of cards (Appendix IV) that will convert the program as contained in Appendix II into the slightly different machine language required when the program is used on the CDC 6500 model computers, instead of the IBM 630 models for which this program is written. Before using this conversion program two steps must be taken,

(1) all data and system control cards must be removed and the remaining portions of the included program become the data deck for "BCD"

(2) All output formats that involve printed words or combinations of printed words and numbers must be converted to "H" format.

5. Output from the Computer.

The output from the computer consists of several possible combinations of data. Included are examples of a few of the possible combinations. All the output from a given trace is printed on a single individual page, headed by the trace number within the data sequence and the positional data for that slide (if any). Figure 7 shows one of the sets of real data that was taken from some data traces made by Tully in the vicinity of Ocean Station "Papa" in 1963. Figure 7 is a hand-drawn enlargement of a real test trace containing both transients and a single main thermocline, typical of that region, used in testing out this program. Figure 8 is a typical output from the program's analysis of this trace and lists the positional data (which was partially available) and the date and time of the trace. The program then reveals the existence of two transients, by printing out the location of the start and end of each transient. It also gives the information on the single major thermocline. In this case the data was read in from a data dekc after being transcribed from the trace onto aperture cards. The data interval was taken in this case to be 0.1 degrees. Figure 9 shows the typical printout of a hand-constructed case, also used to test program, centered around a thermal inversion (Boston 1966). Figure 10 is the data output for this created case. Figure 12 is an example of the printed output that would be expected from a trace (see Figure 11) containing multiple thermoclines. In this case two major thermoclines exist in the trace. For interest, Figure 13 shows the output from the drawing routine called from SEE13. It can be seen that computer drawn trace of Figure 13 is an adequate enough representation of Figure 12 to enable the user to use this type of computer output as a rough aid in insuring correct working of the computer program or other rough calculations where a visual presentation might be desirable.

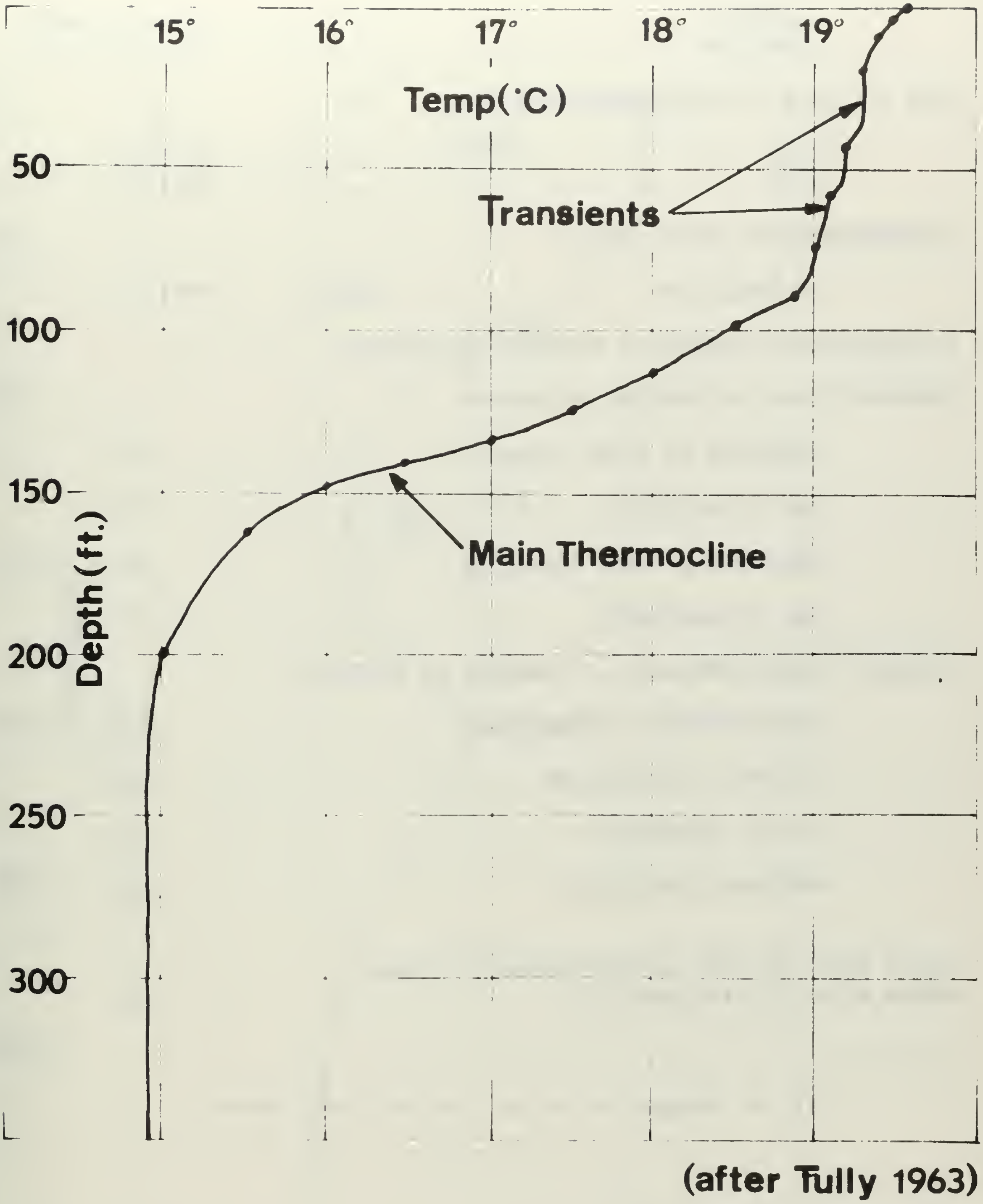


Fig. 7 Ocean Station 'Papa' — BT Trace
23 April 1963

```
START OF INVESTIGATIONS IN BATHYTHERMOGRAPH TRACE NUMBER 4

GEOGRAPHIC POSITION OF BATHYTHERMOGRAPH TRACE:

          LATITUDE  . . . . . . . . . . . . . . . . . . . 36-36.1 NORTH
          LONGITUDE  . . . . . . . . . . . . . . . . . .113-44.7 WEST

DATE AND TIME OF BATHYTHERMOGRAPH TRACE:

          DATE  . . . . . . . . . . . . . . . . . . . . .10/23/63
          TIME  . . . . . . . . . . . . . . . . . . . . .100832

BATHYTHERMOGRAPH SERIAL NUMBER:

          BT SERIAL NO  . . . . . . . . . . . . . . . . .663977

NO TEMPERATURE INVERSIONS EXIST IN THIS TRACE.

TRANSIENT DATA AS COMPUTED BY PROGRAM:

          BEGINNING OF FIRST TRANSIENT. . . . . . . . .      21.0

          END OF TRANSIENT  . . . . . . . . . . . . . .      55.0

          BEGINNING OF NEXT TRANSIENT . . . . . . . . .      60.0

          END OF TRANSIENT  . . . . . . . . . . . . . .      87.2

MULTIPLE THERMOCLINE DATA AS COMPUTED BY PROGRAM:

          CENTER NUMBER 1 LOCATED AT . . . . . . . . .      148.0

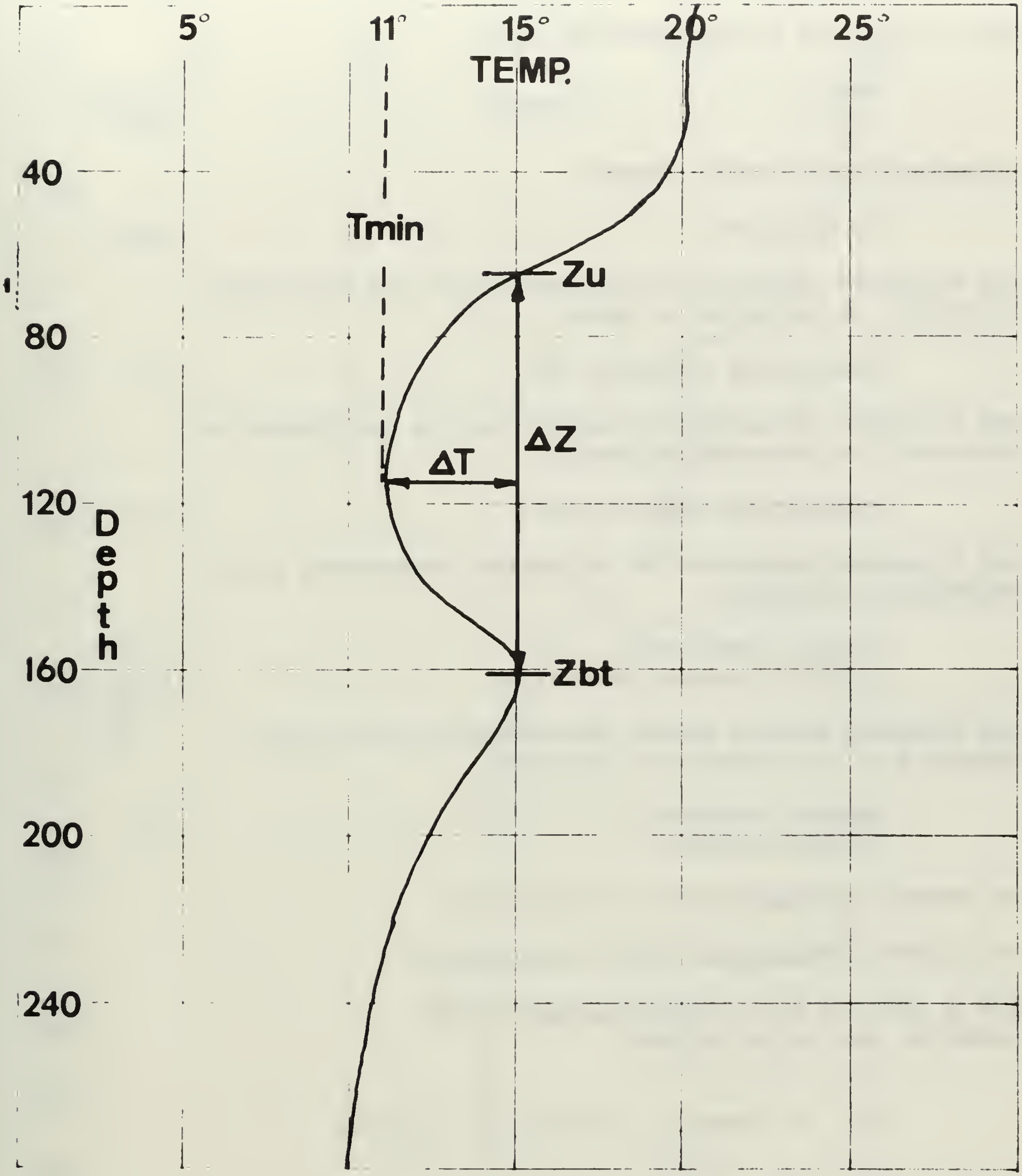
          CENTER OF THERMOCLINE . . . . . . . . . . . .     149.6

          TOP OF THERMOCLINE  . . . . . . . . . . . . .      99.3

          BOTTOM OF THERMOCLINE . . . . . . . . . . . .     196.8


END OF DATA FOR THIS BATHYTHERMOGRAPH SLIDE.
NUMBER OF DATA PAIRS ANALYZED -                             18
```

Fig. 8 Example of Output for Real Data Curve



(after Boston, 1966)

Fig. 9 Typical Inversion

```
START OF INVESTIGATIONS IN BATHYTHERMOGRAM TRACE NUMBER 27

GEOGRAPHIC POSITION OF BATHYTHERMOGRAPH TRACE:

          LATITUDE . . . . . . . . . . . . . . . . . .    00.00
          LONGITUDE . . . . . . . . . . . . . . . . . .   00.00

DATE AND TIME OF BATHYTHERMOGRAPH TRACE:

          DATE . . . . . . . . . . . . . . . . . . . .    00/00/00
          TIME . . . . . . . . . . . . . . . . . . . .    000000

BATHYTHERMOGRAPH SERIAL NUMBER:

          BT SERIAL NO . . . . . . . . . . . . . . . .    000000

THE FOLLOWING INDICATES THE COMPUTED TOP OF THE TEMPERATURE
INVERSION, BY NON-GAUSSIAN THEODS:

          TEMPERATURE INVERSION TOP . . . . . . . . . .    66.0

THE FOLLOWING INDICATES THE COMPUTED BASE OF THE TEMPERATURE
INVERSION, BY NON-GAUSSIAN METHODS:

          TEMPERATURE INVERSION BASE. . . . . . . . . .   160.1

THE FOLLOWING FIGURES DEFINE THE MINIMUM TEMPERATURE OF THE
TEMPERATURE INVERSION:

          MINIMUM TEMPERATURE . . . . . . . . . . . . .    11.0
          DEPTH OF MINIMUM TEMPERATURE  . . . . . . . .   139.4

THE FOLLOWING FIGURES DENOTE THE TEMPERATURE AND SPACIAL
MAGNITUDE OF THE TEMPERATURE INVERSION:

          THERMAL MAGNITUDE   . . . . . . . . . . . . .     4.0
          SPACIAL MAGNITUDE   . . . . . . . . . . . . .    94.1

NO THERMAL TRANSIENTS EXIST IN THIS TRACE.

NO MULTIPLE THERMOCLINES EXIST IN THIS TRACE.

END OF DATA FOR THIS BATHYTHERMOGRAPH SLIDE.
NUMBER OF DATA PAIRS ANALYZED -
```

Fig. 10 Example of Output for Inversion

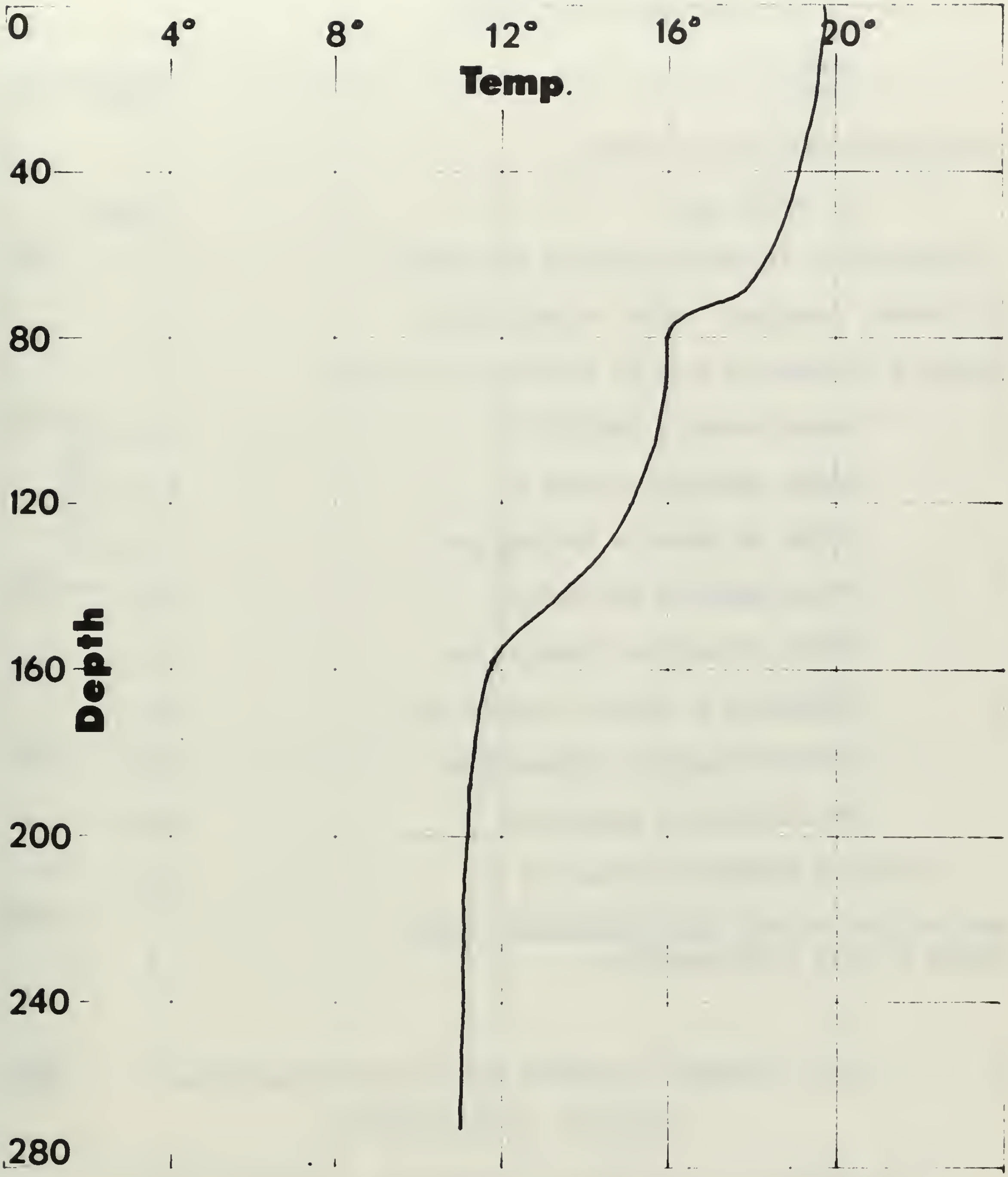


Fig.11 Hand drawn Bathythemogram

```
START OF INVESTIGATIONS IN BATHYTHERMOGRAM TRACE NUMBER  17

GEOGRAPHIC POSITION OF BATHYTHERMOGRAPH TRACE:

          LATITUDE . . . . . . . . . . . . . . . . . .    000.00 NORTH
          LONGITUDE . . . . . . . . . . . . . . . . . .    000.00 WEST

DATE AND TIME OF BATHYTHERMOGRAPH TRACE:

          DATE . . . . . . . . . . . . . . . . . . . .    00/00/00
          TIME . . . . . . . . . . . . . . . . . . . .    00000

BATHYTHERMOGRAPH SERIAL NUMBER:

          BT SERIAL NO. . . . . . . . . . . . . . . . .    000000

NO TEMPERATURE INVERSION EXIST IN THIS TRACE.

NO THERMAL TRANSIENTS EXIST IN THIS TRACE.

MULTIPLE THERMOVLINE DATA AS COMPUTED BY PROGRAM:

          CENTER NUMBER 1 LOCATED AT . . . . . . . . .     72.0

          CENTER NUMBER 2 LOCATED AT . . . . . . . . .    144.0

          CENTER OF GAUSSIAN THERMOCLINE . . . . . . .     75.0

          TOP OF GAUSSIAN THERMOCLINE . . . . . . . . .     53.5

          BOTTOM OF GAUSSIAN THERMOCLINE . . . . . . .     94.4

          SEPERATION #1 BETWEEN THERMOCLINES . . . . .    100.0

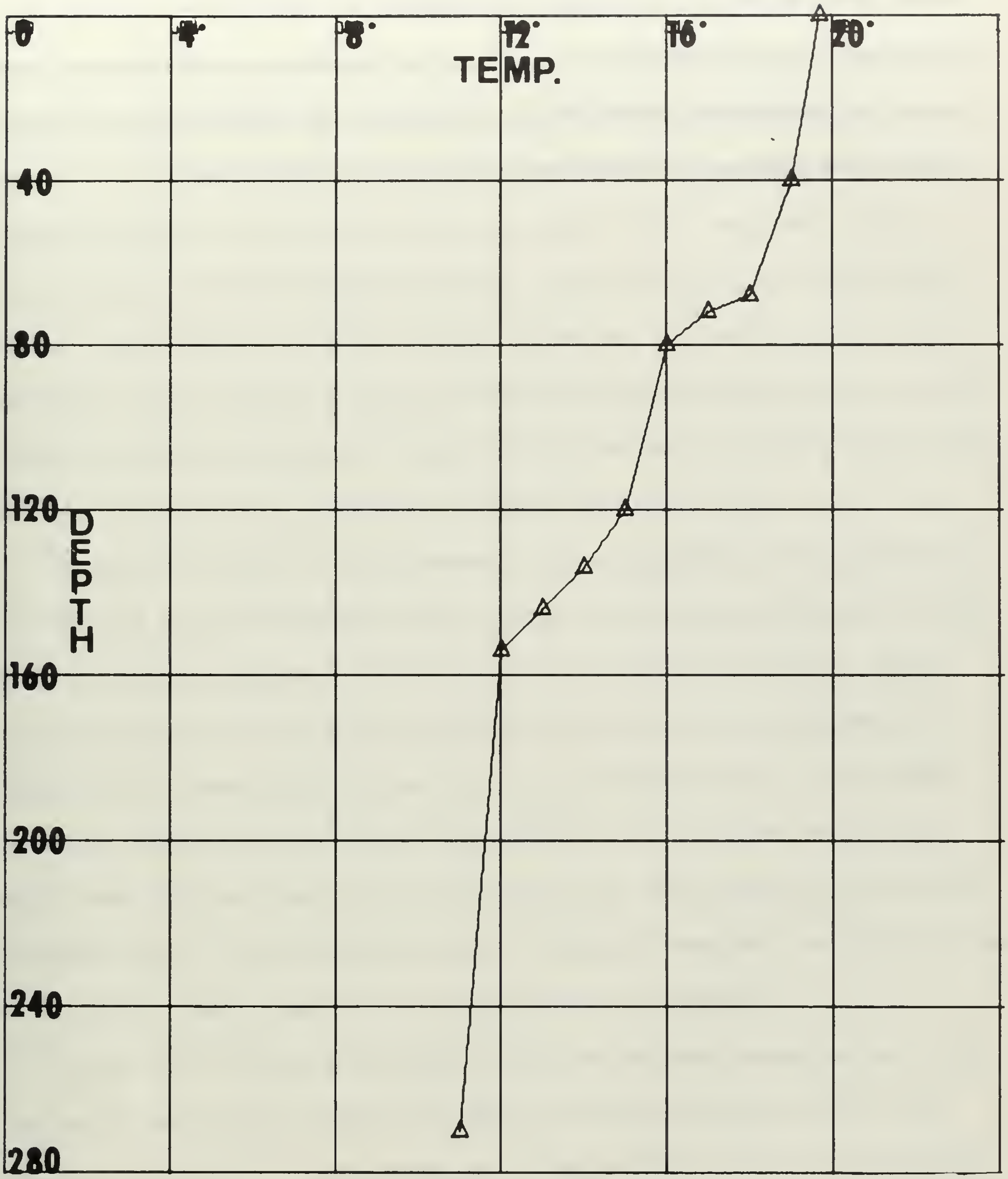
          CENTER OF GAUSSIAN THERMOCLINE . . . . . . .    138.0

          TOP OF GAUSSIAN THERMOCLINE . . . . . . . . .    104.9

     BOTTOM OF GAUSSIAN THERMOCLINE . . . . . . . . . .    152.6

END OF DATA FOR THIS BATHYTHERMOGRAPH SLIDE.
NUMBER OF DATA PAIRS ANALYZED -                           8
```

Fig. 12 Example of Output for Multiple Thermoclines



COMPUTER TRACE
TEMPERATURE AGAINST DEPTH (Z POS. UP)
FIG.13

All the preceeding traces were read in in data deck format, with varied intervals of delta-T, 0.1 degrees in the first example, 1.0 degrees in the second case, and 0.5 degrees in the latter case. There are other possible combinations, but these three cases outline the general format and the answers that can be expected. The other cases are just various combinations or omissions of the above three cases.

6. Discussion and Conclusions Concerning Results.

Although no error analysis was undertaken for this computer process, it is obvious that there are some errors built into the program that could perhaps be reduced by further investigation and refinement. In several segments we use a Gaussian based method and thus there is some error introduced in the computation of the top and bottom of the thermocline due to having to compute a sigma in the program. Also, in this program the multiplication factor, SK, is calculated only roughly based on the thermal interval. This factor can be improved, but cannot be exact in the computer, due to truncation error; besides, much storage space is needed to store the large table of values applicable where each tabular figure is only good for one specific set of data.

There are certain errors inherent in the computer, but since we do not require great precision, these errors can be ignored due to the fact that the bathythermograph itself is not a precise instrument. These errors include truncation and round-off errors in every computation. Since we are requiring printout to only one decimal place it is doubtful that these errors will ever be noticable. Also there are errors built into the functions that are interral to the computer, such as the "square root," "multiplication," and "addition" routines, but again these will not be significant in the accuracy that we require.

There are certain advantages to the use of data tapes versus magnetic cards, when great volumes of data are to be processed. The time required to punch the data cards and to check the results is a function of the experience of the operator. The computer time is approximately 25 seconds for card input computations, plus additional time if the drawing of graphs is required (approximately three minutes per graph). This time can be cut approximately in half if the program compiled by the computer is put on tape and data input is in that form, as the compiler takes approximately half the time now used in making a computer run.

There are other equipment errors, that as yet have not been evaluated,that are concerned with the input data, and are still vital to the person desiring to analyze the traces by use of this program. Such items as hysteresis, where a double trace is formed on the bathythermograph slide, due to slight differences in the temperature when raising the Bathythermograph as compared to when lowering it cause inaccuracies, dull styluses can give traces that are too wide to be useful. Damaged equipment that gives unacceptable temperature fluctuations, such as variations from bucket thermometer temperatures, or other signs that the bathythermogram is inaccurate although the trace itself appears acceptable is another input error. Also there are errors inherent in the digitizer that can vary depending upon the equipment used and the usual problems inherent to electronic curve followers or other devices.

The results of this program, in the fifty test cases run, appear to give slight errors as compared to the hand analysis of the same data. Ten of the test cases were hand constructed curves, designed to test the program for specific features or combinations of these features, and the remaining data were real data obtained from the Fleet Numerical Weather Central or taken from other written works, such as Tully and Dodimead (1957) and Pattullo and Cochrane (1951), and a few traces taken in Monterey Bay. Both tape inputs from Fleet Numerical Weather Central and punched tape data decks were used. There were no apparent differences between the outputs from the digitized data and the data on aperature cards, as might be expected assuming that care was taken by the person picking off data points from the curves. The largest error in the tested cases, was found in a very steep thermocline, real data case, where the depth error was 4.5 feet for the top of the thermocline and 3.0 feet for the base of the thermocline in a thermocline that was 76 feet in vertical magnitude. In this case the center of the thermocline was only 0.3 feet from the hand calculated value. The thermal interval was 1.0 degree Farenheit and the thermocline in question was analyzed by the Gaussian technique.

Thus it can be said that this program accomplishes, with acceptable accuracy, considering the analytic methods used, in seconds what a well trained operator would take tens of minutes to accomplish.

This program can be expanded, by the inclusion of additional subroutines, and their respective "call" cards in the MAIN routine without greatly increasing the time needed in computing the desired results.

7. Recommendations.

As previously stated, there are other features that can be added to this program by merely including additional subroutines. Additionally, this same programming technique can be used, with a few basic changes, to analyze other oceanographic data curves. Before accomplishing any conversions of this program to handle other data, the user must first look at the basic form of the traces he plans to analyze. Traces, other than temperature, may not be describable using the same parameters as described by Tully (1964). Such items as the magnitude of the fluctuations of other quantities must be examined as they may exceed the number that this program can handle. For example, it may be common, in some other oceanographic parameter, to have more than three stable features corresponding to the thermoclines in this program, and thus the program would have to be modified to allow for additional curve computations. Another correction that would have to be made would be the rewording of the printout statements.

Further investigations should be undertaken, to include the improvement in accuracy of sigma and SK parameters and the possibility that such curves as the hyperbolic tangent or Chi-squared curves might give a better curve fit.

As this program has yet to be run on the CDC 6500 computer of the Fleet Numerical Weather Central, this should be undertaken as soon as possible. For this type of program, the speed of computation on the CDC 6500 computer is approximately three times that of the IBM 360. This CDC 6500 computer also contains more storage space than the IBM 360 computer and thus longer tapes or card inputs may be used. An additional advantage of this increased storage is that investigation could be shifted from the present two dimensional set up (temperature versus depth) to a three dimensional investigation (multiple traces analyzed simultaneously) giving a field representation instead of just specific points.

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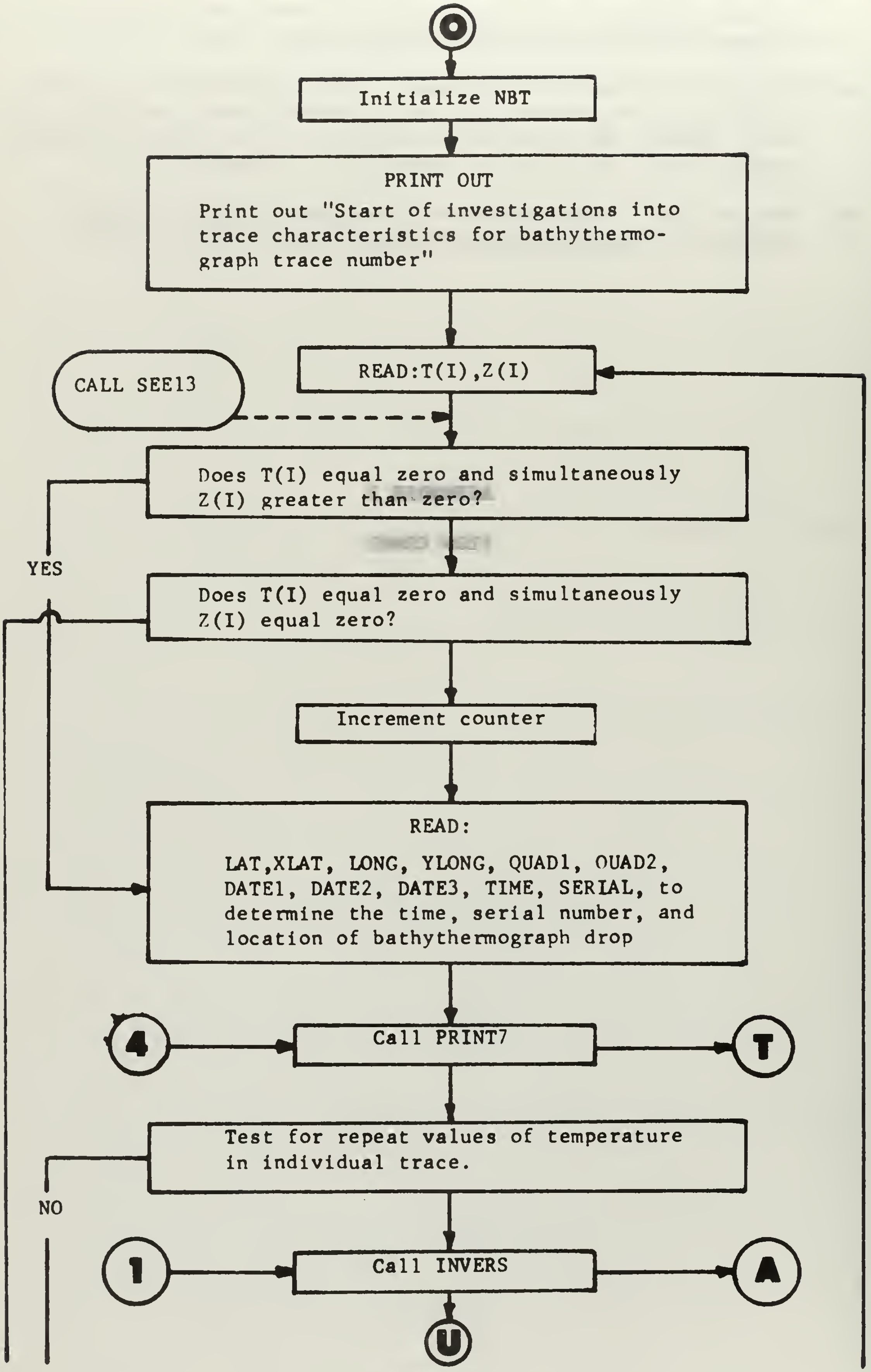
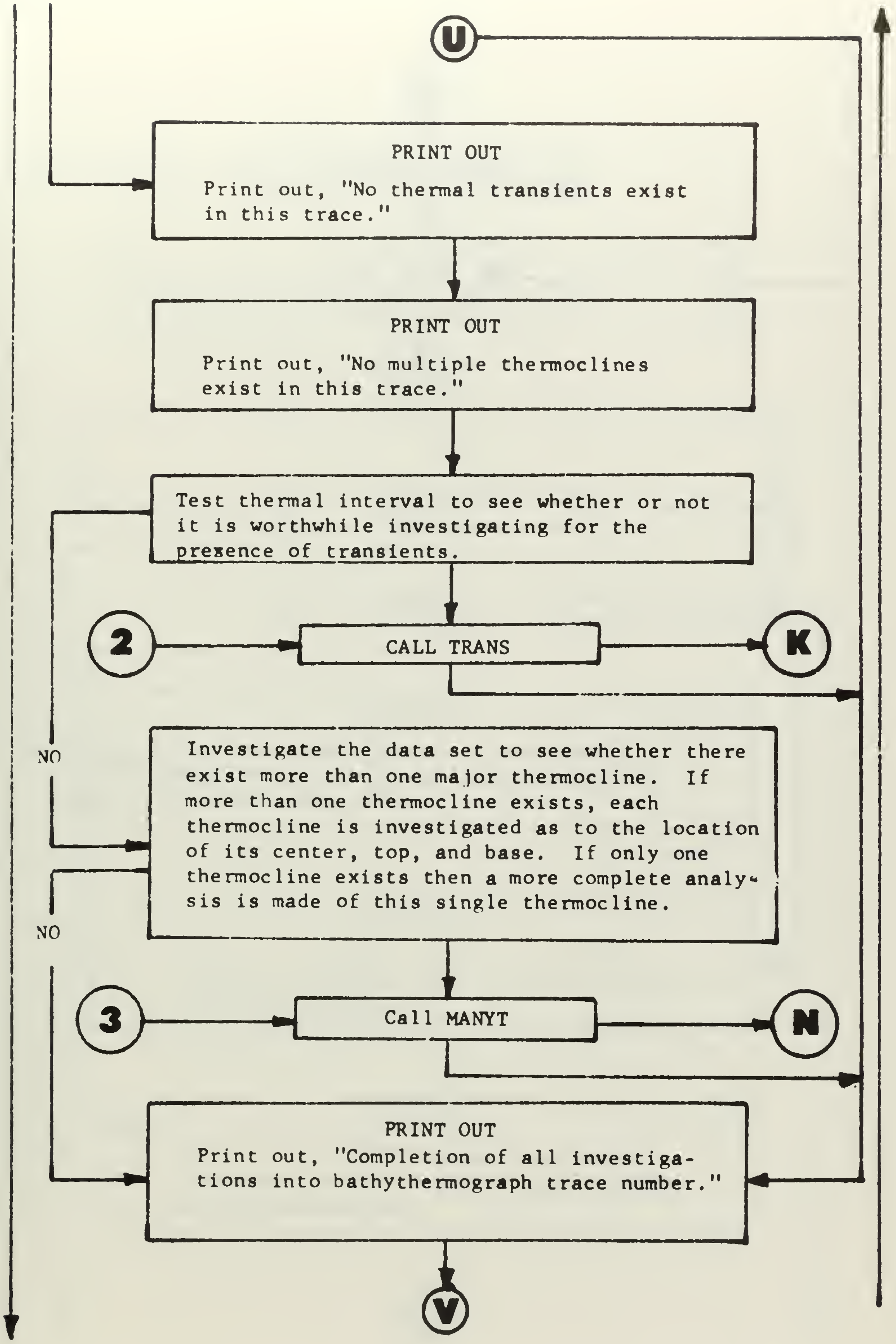
APPENDICES

APPENDIX I

FLOW CHART


O
Initialize NBT
PRINT OUT
Print out "Start of investigations into trace characteristics for bathythermograph trace number"
READ:T(I),Z(I)
CALL SEE13
Does T(I) equal zero and simultaneously Z(I) greater than zero?
YES
Does T(I) equal zero and simultaneously Z(I) equal zero?
Increment counter
READ:
LAT,XLAT, LONG, YLONG, QUAD1, OUAD2, DATE1, DATE2, DATE3, TIME, SERIAL, to determine the time, serial number, and location of bathythermograph drop
4
Call PRINT7
T
Test for repeat values of temperature in individual trace.
NO
1
Call INVERS
A
U



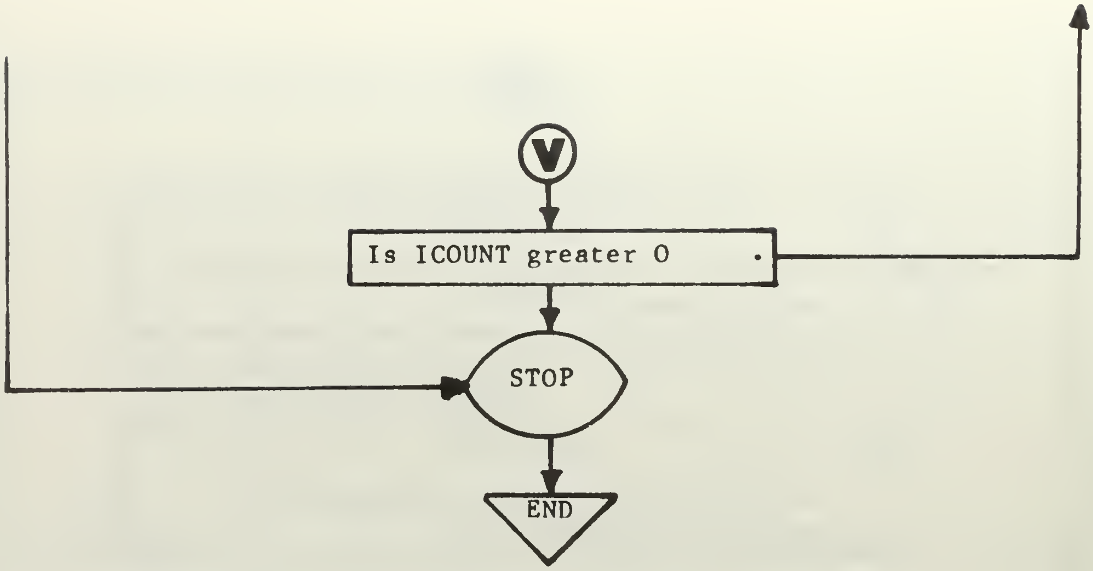
Print out, "No thermal transients exist in this trace."

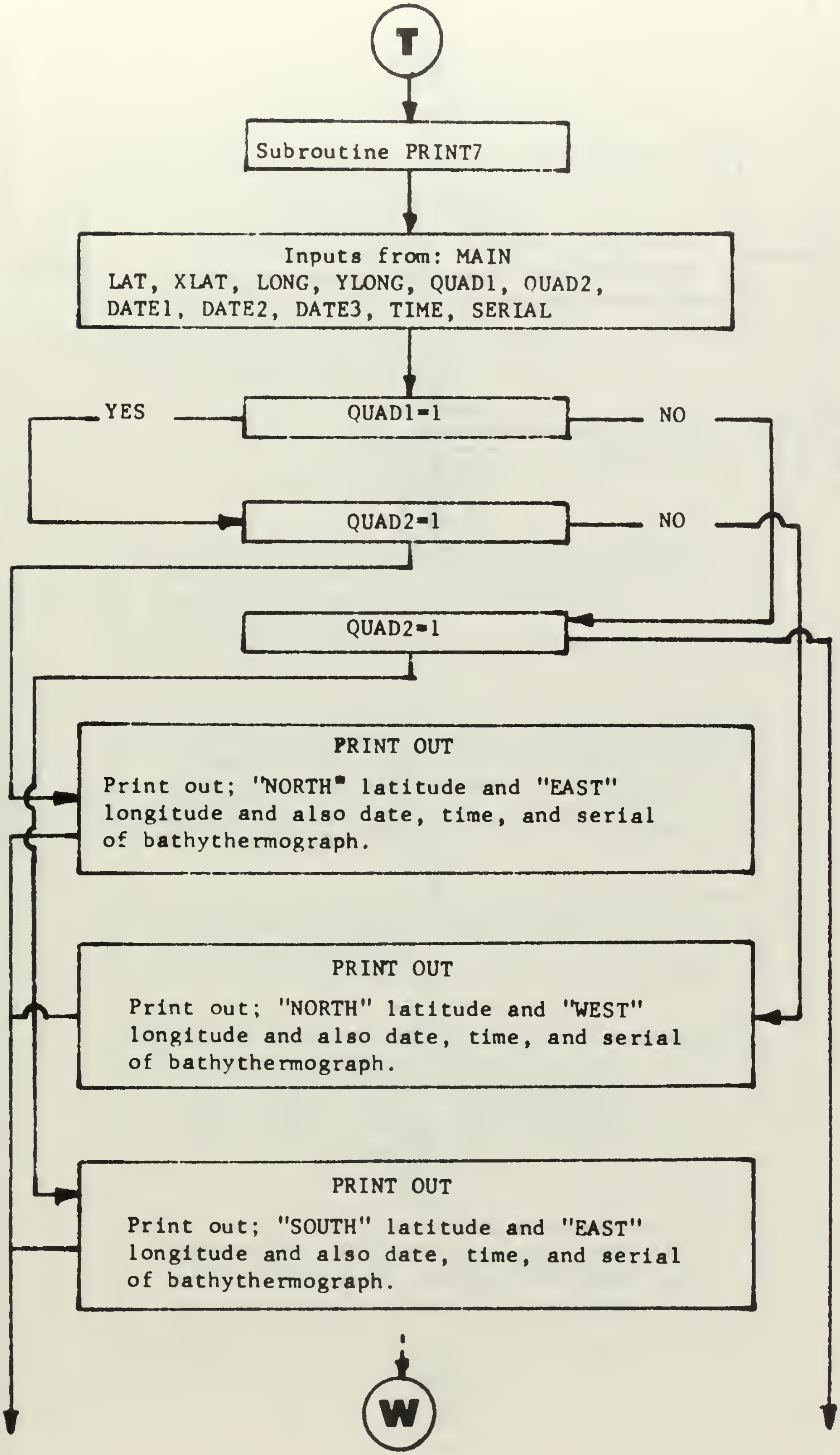
Print out, "No multiple thermoclines exist in this trace."

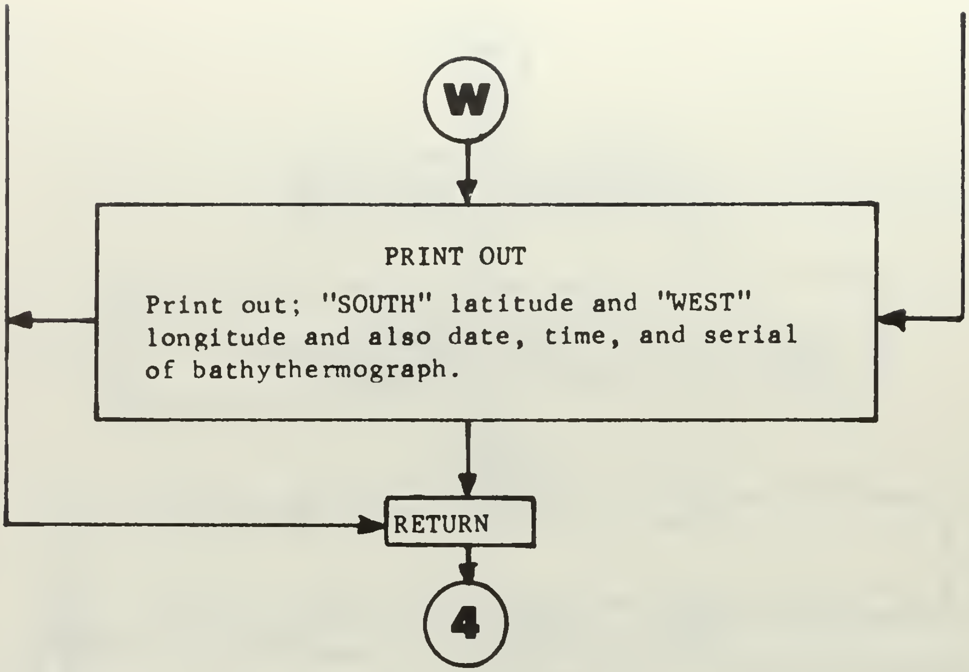
Test thermal interval to see whether or not it is worthwhile investigating for the prexence of transients.

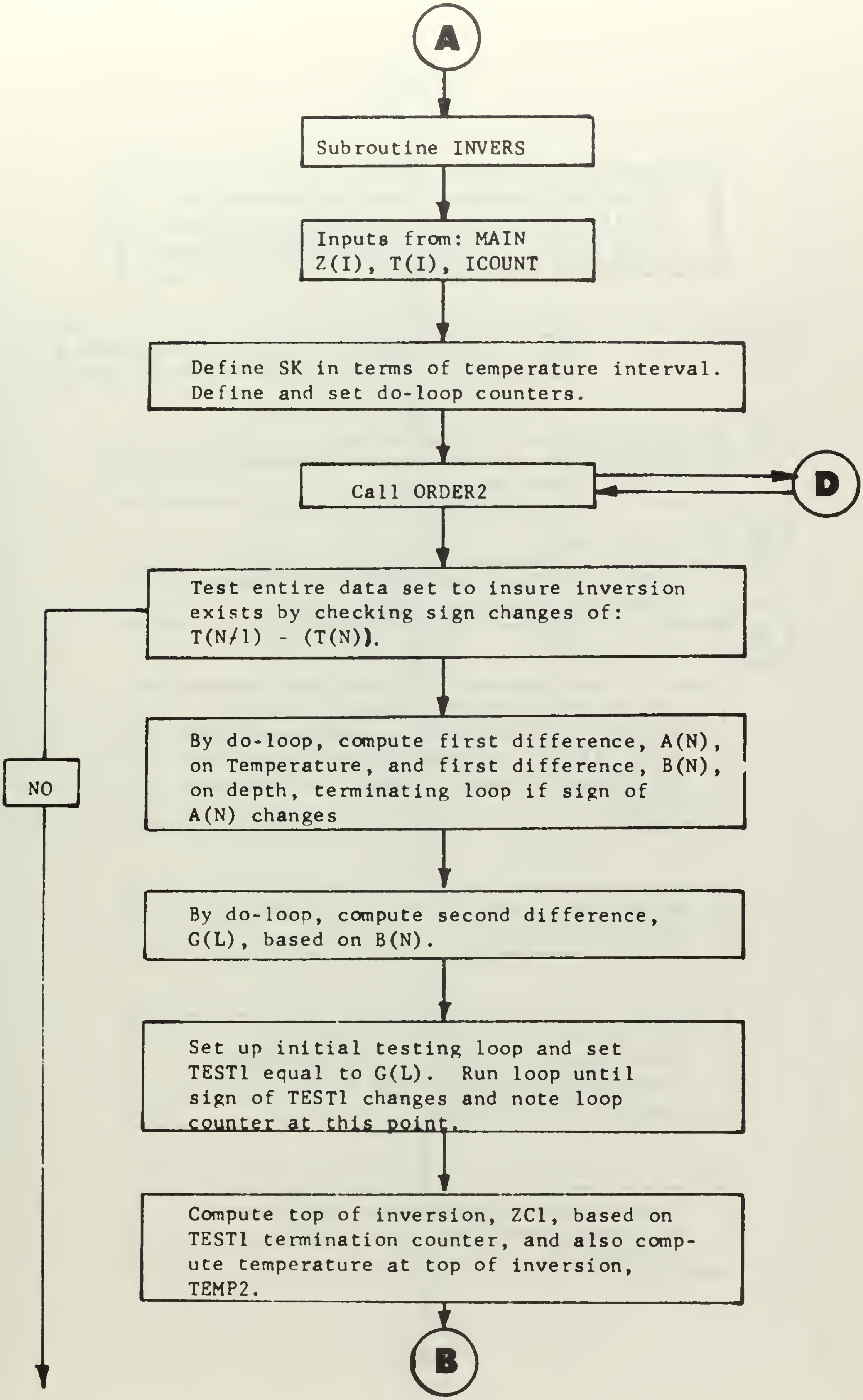
Investigate the data set to see whether there exist more than one major thermocline. If more than one thermocline exists, each thermocline is investigated as to the location of its center, top, and base. If only one thermocline exists then a more complete analysis is made of this single thermocline.

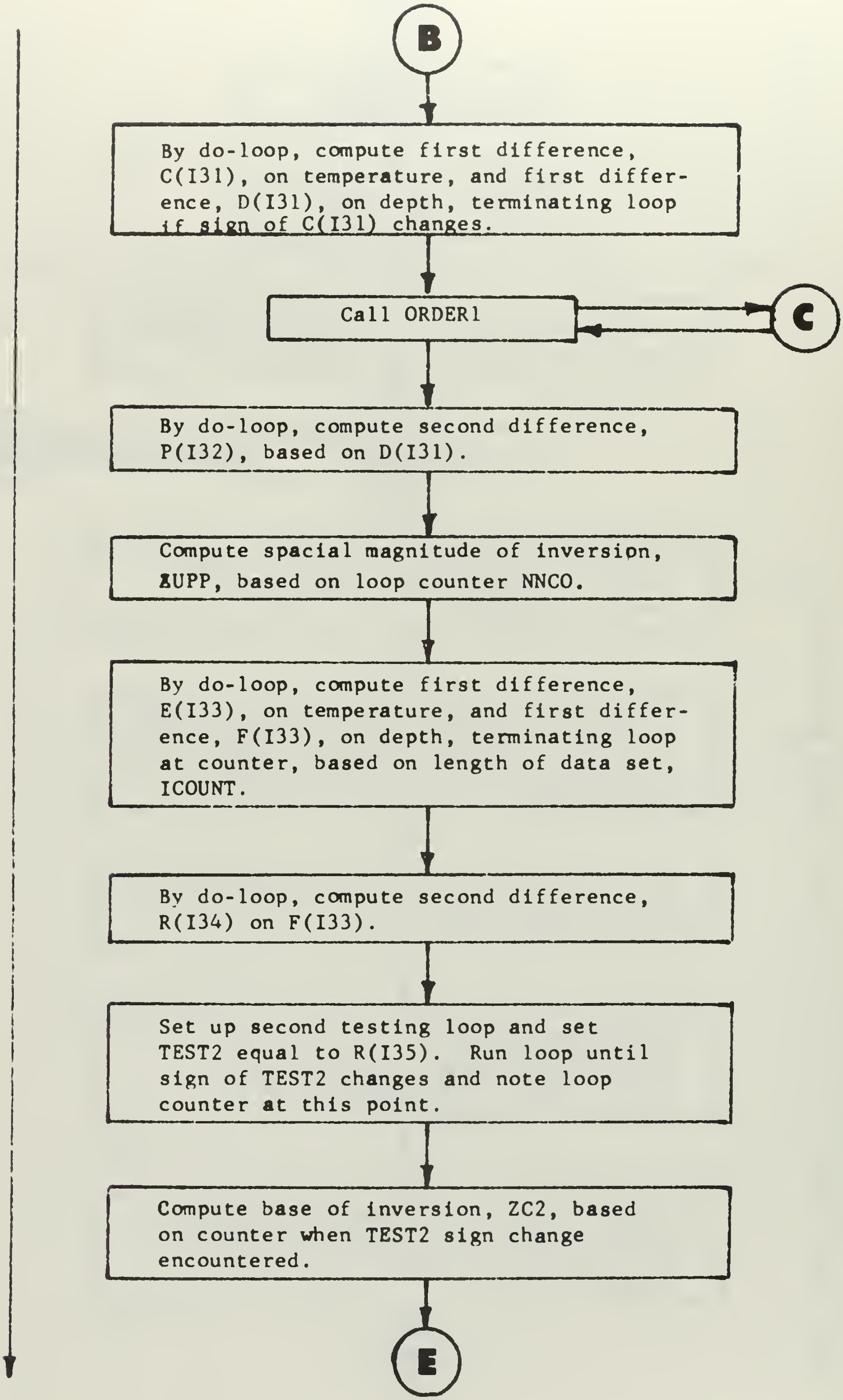
Print out, "Completion of all investigations into bathythermograph trace number."


V
Is ICOUNT greater 0 .
STOP
END


T
Subroutine PRINT7
Inputs from: MAIN
LAT, XLAT, LONG, YLONG, QUAD1, QUAD2,
DATE1, DATE2, DATE3, TIME, SERIAL
YES
QUAD1=1
NO
QUAD2=1
NO
QUAD2=1
PRINT OUT
Print out; "NORTH" latitude and "EAST" longitude and also date, time, and serial of bathythermograph.
PRINT OUT
Print out; "NORTH" latitude and "WEST" longitude and also date, time, and serial of bathythermograph.
PRINT OUT
Print out; "SOUTH" latitude and "EAST" longitude and also date, time, and serial of bathythermograph.
W


W
PRINT OUT
Print out; "SOUTH" latitude and "WEST" longitude and also date, time, and serial of bathythermograph.
RETURN
4


A
Subroutine INVERS
Inputs from: MAIN Z(I), T(I), ICOUNT
Define SK in terms of temperature interval. Define and set do-loop counters.
Call ORDER2
D
Test entire data set to insure inversion exists by checking sign changes of: T(N/1) - (T(N)).
NO
By do-loop, compute first difference, A(N), on Temperature, and first difference, B(N), on depth, terminating loop if sign of A(N) changes
By do-loop, compute second difference, G(L), based on B(N).
Set up initial testing loop and set TEST1 equal to G(L). Run loop until sign of TEST1 changes and note loop counter at this point.
Compute top of inversion, ZC1, based on TEST1 termination counter, and also compute temperature at top of inversion, TEMP2.
B



By do-loop, compute first difference, C(I31), on temperature, and first difference, D(I31), on depth, terminating loop if sign of C(I31) changes.

Call ORDER1

By do-loop, compute second difference, P(I32), based on D(I31).

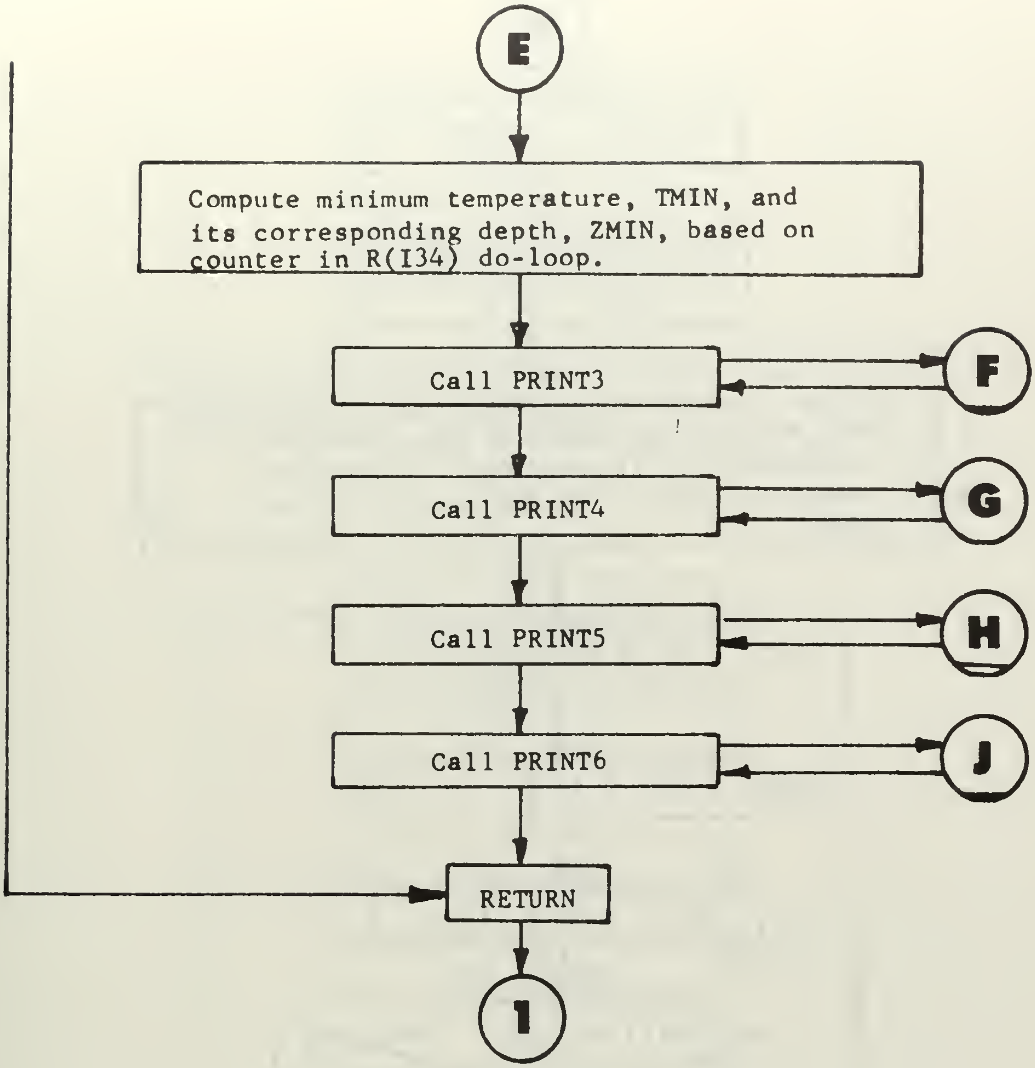
Compute spacial magnitude of inversion, ZUPP, based on loop counter NNCO.

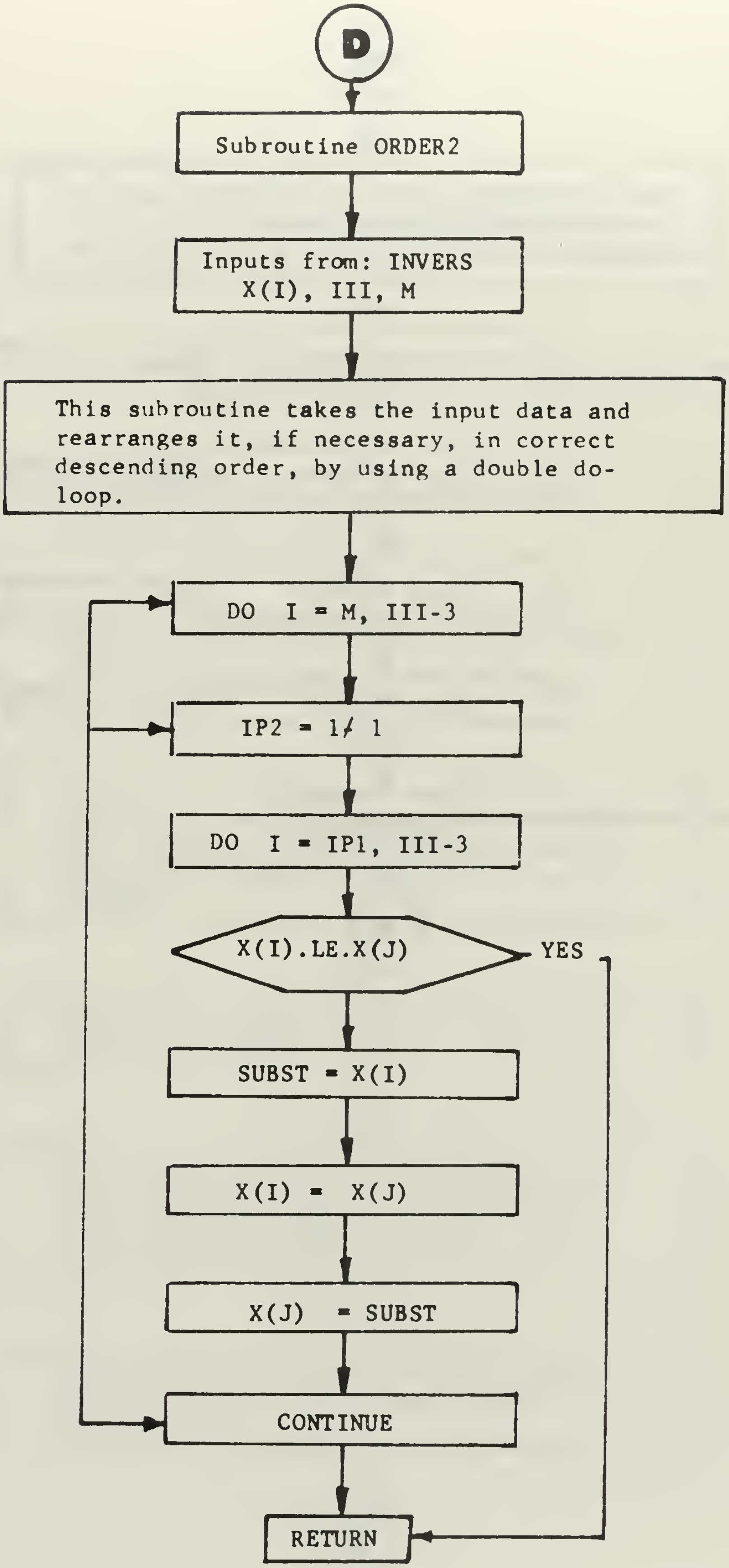
By do-loop, compute first difference, E(I33), on temperature, and first difference, F(I33), on depth, terminating loop at counter, based on length of data set, ICOUNT.

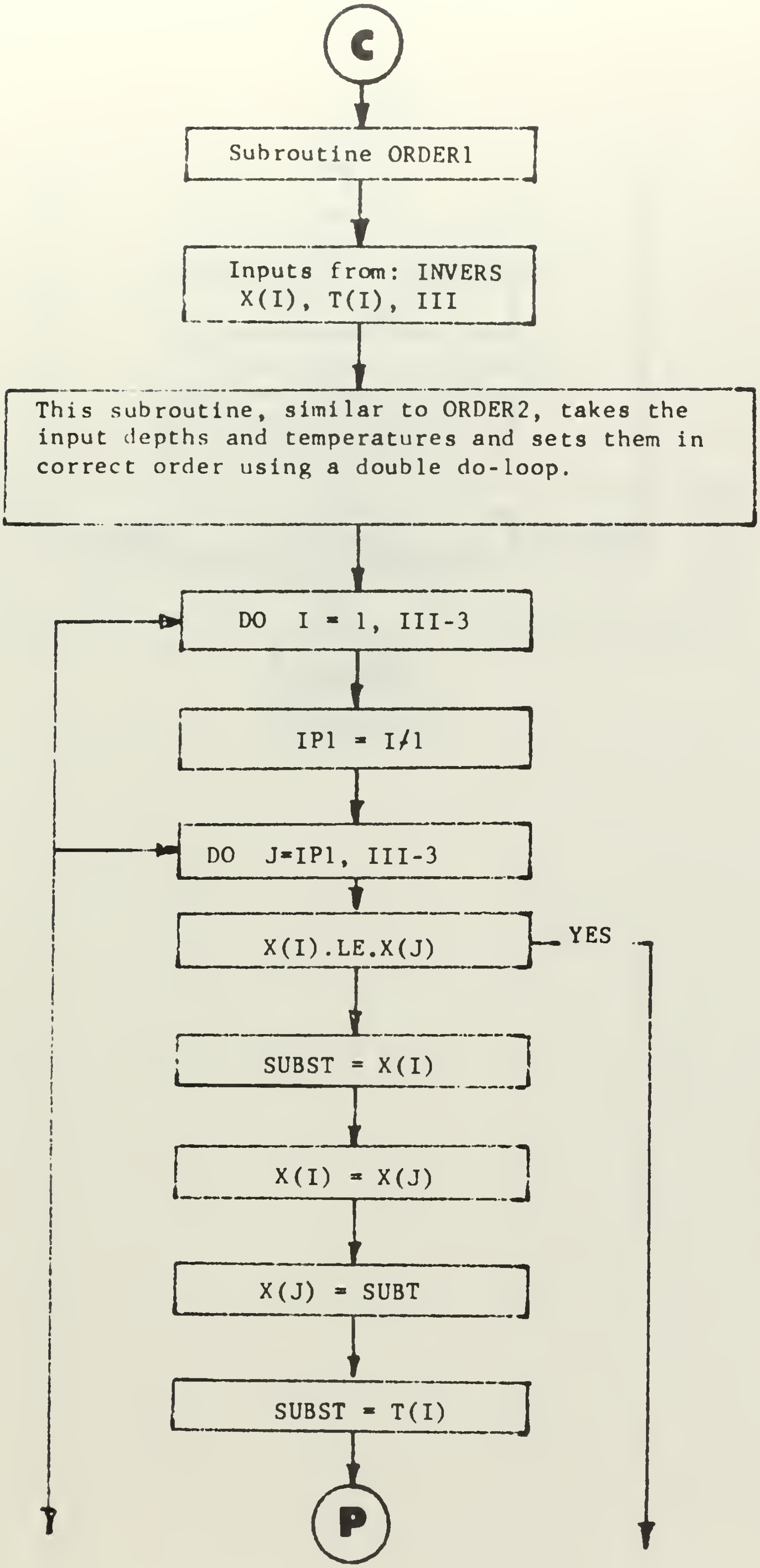
By do-loop, compute second difference, R(I34) on F(I33).

Set up second testing loop and set TEST2 equal to R(I35). Run loop until sign of TEST2 changes and note loop counter at this point.

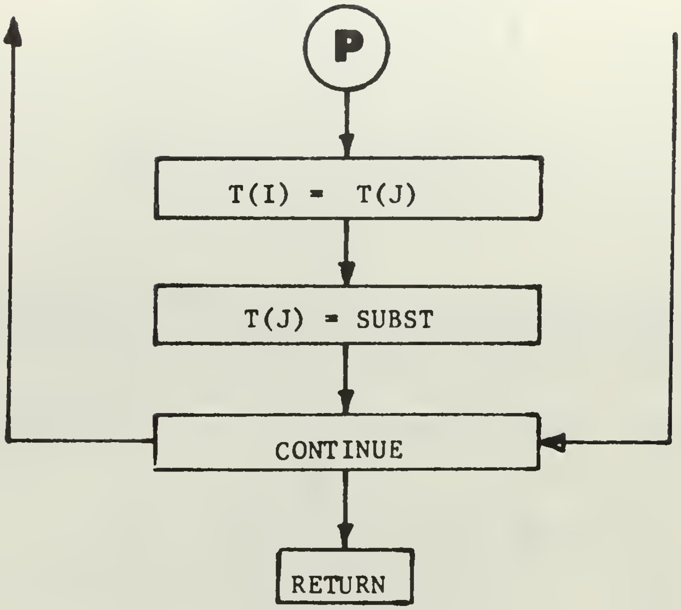
Compute base of inversion, ZC2, based on counter when TEST2 sign change encountered.

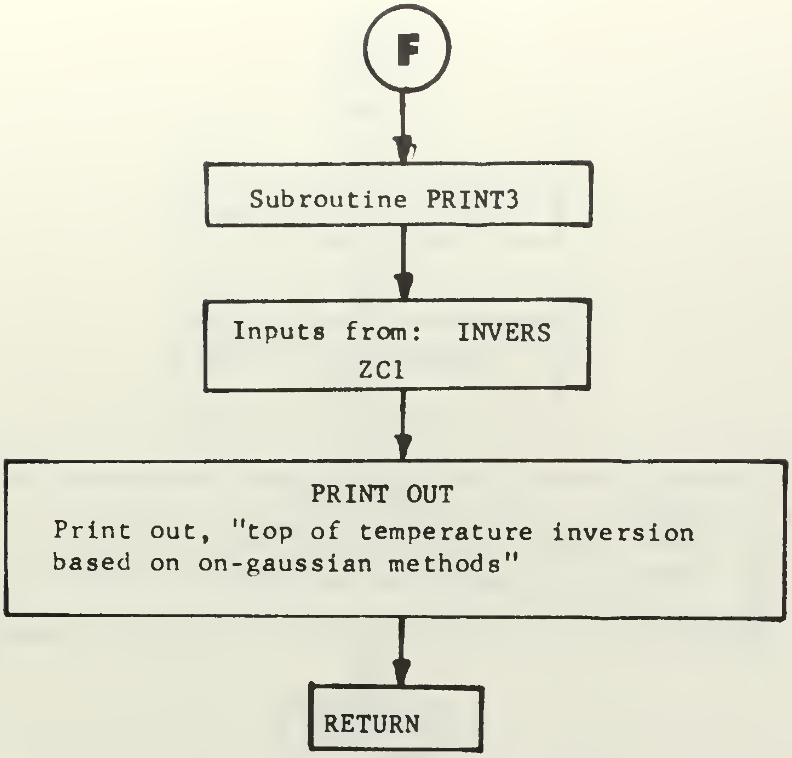

E
Compute minimum temperature, TMIN, and its corresponding depth, ZMIN, based on counter in R(I34) do-loop.
Call PRINT3
F
Call PRINT4
G
Call PRINT5
H
Call PRINT6
J
RETURN
1

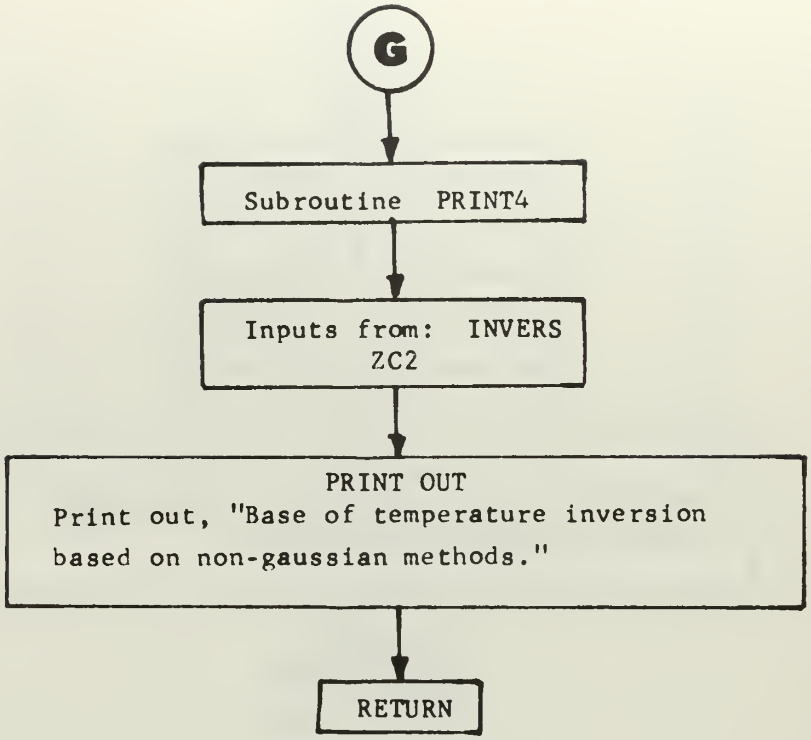

D
Subroutine ORDER2
Inputs from: INVERS
X(I), III, M
This subroutine takes the input data and rearranges it, if necessary, in correct descending order, by using a double do-loop.
DO I = M, III-3
IP2 = 1+ 1
DO I = IP1, III-3
X(I).LE.X(J)
YES
SUBST = X(I)
X(I) = X(J)
X(J) = SUBST
CONTINUE
RETURN

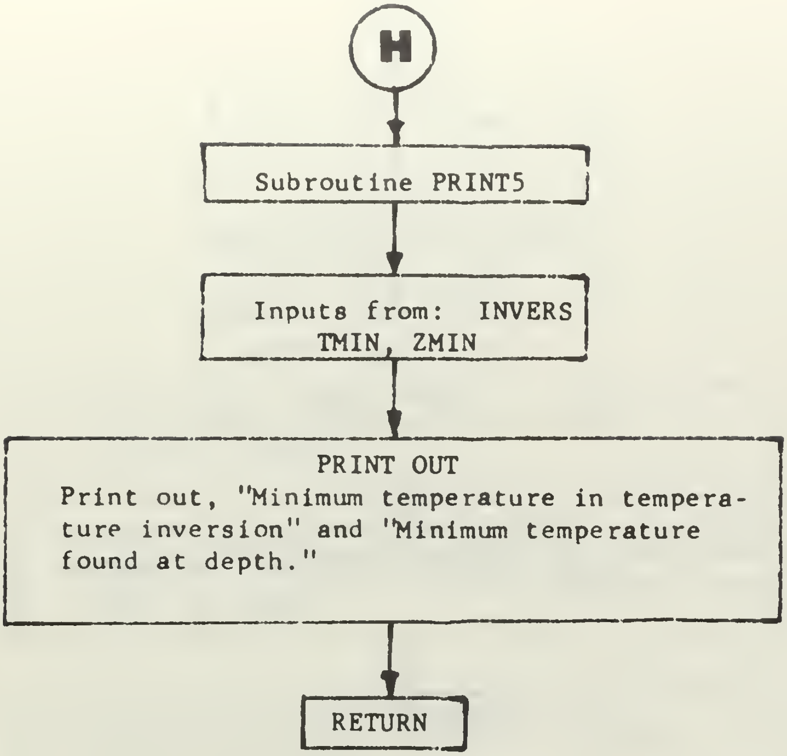


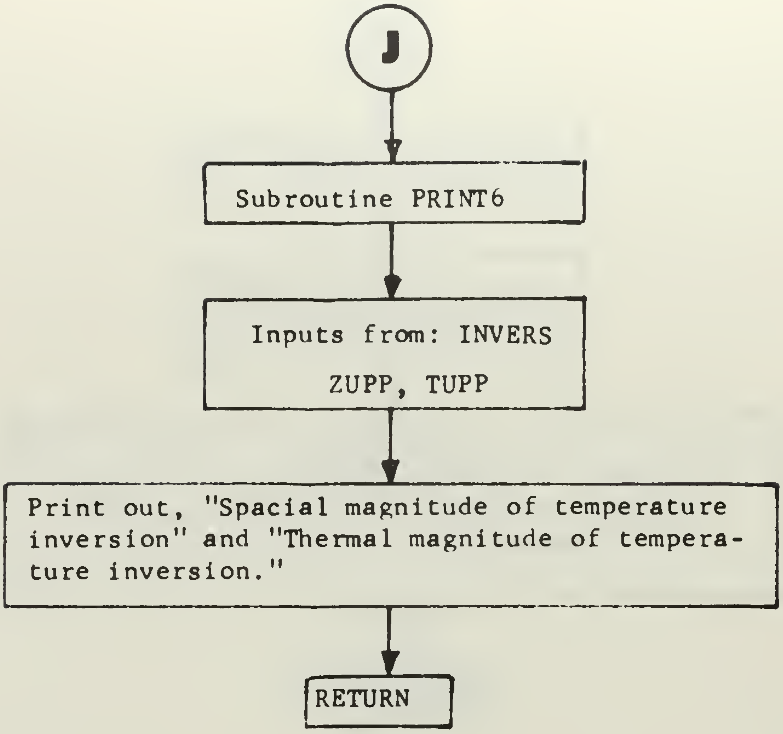
This subroutine, similar to ORDER2, takes the input depths and temperatures and sets them in correct order using a double do-loop.

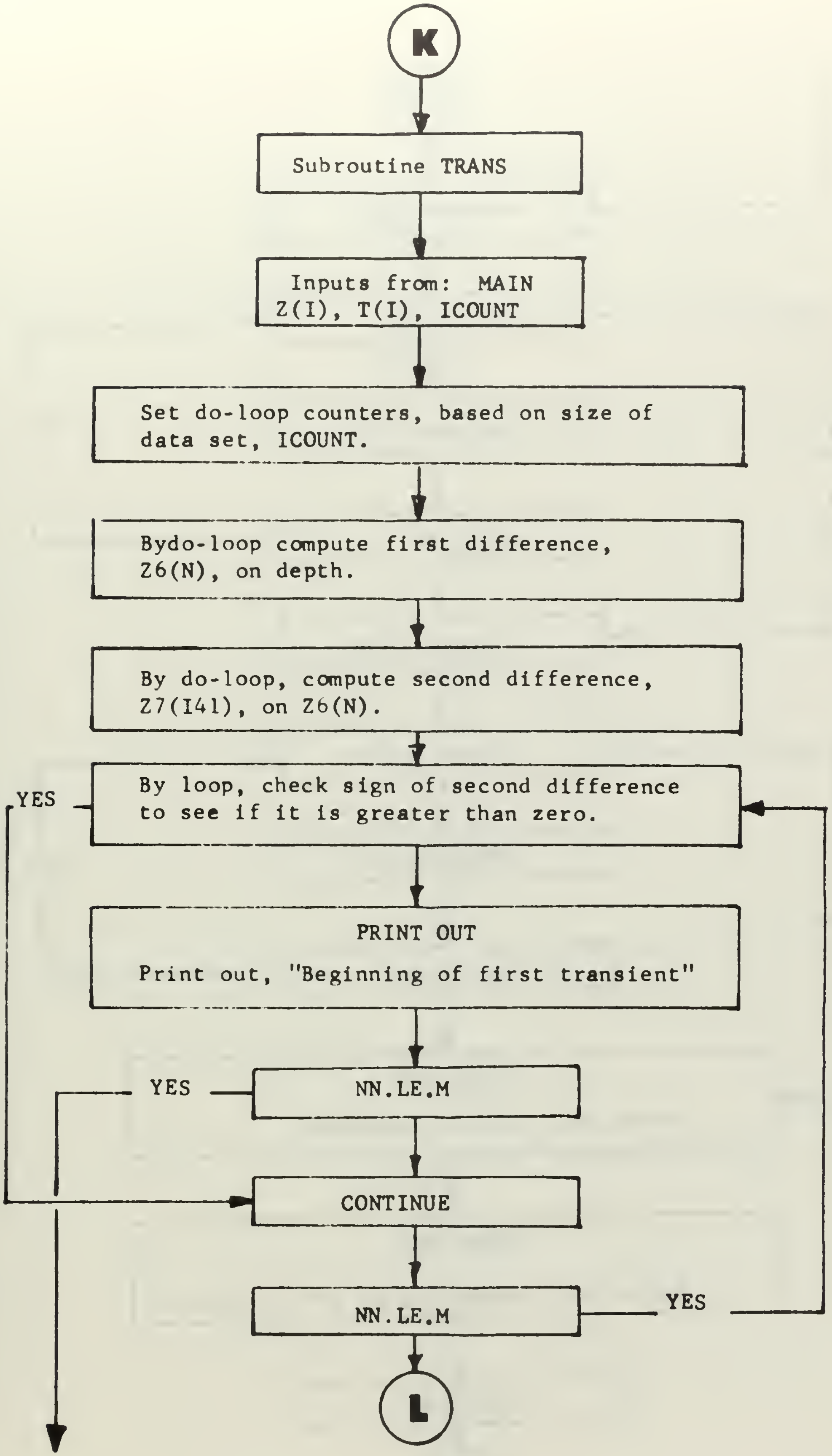

P
T(I) = T(J)
T(J) = SUBST
CONTINUE
RETURN

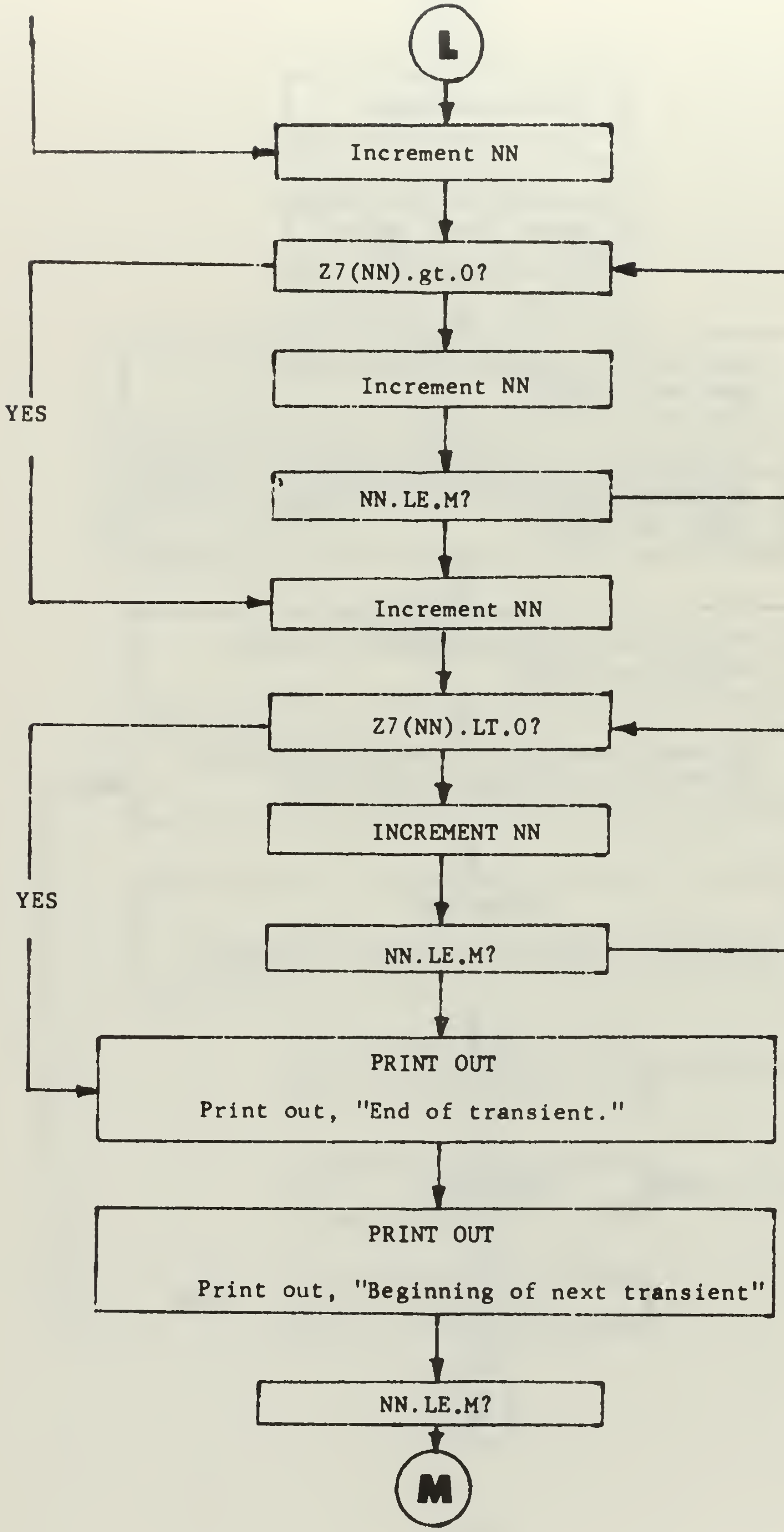

F
Subroutine PRINT3
Inputs from: INVERS
ZC1
PRINT OUT
Print out, "top of temperature inversion based on on-gaussian methods"
RETURN

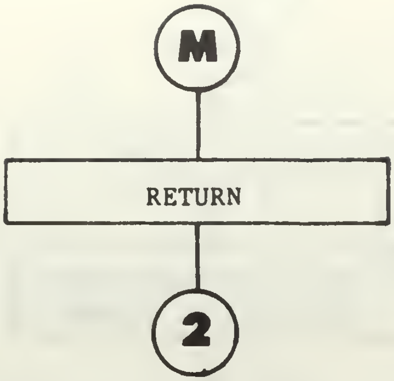

G
Subroutine PRINT4
Inputs from: INVERS
ZC2
PRINT OUT
Print out, "Base of temperature inversion based on non-gaussian methods."
RETURN

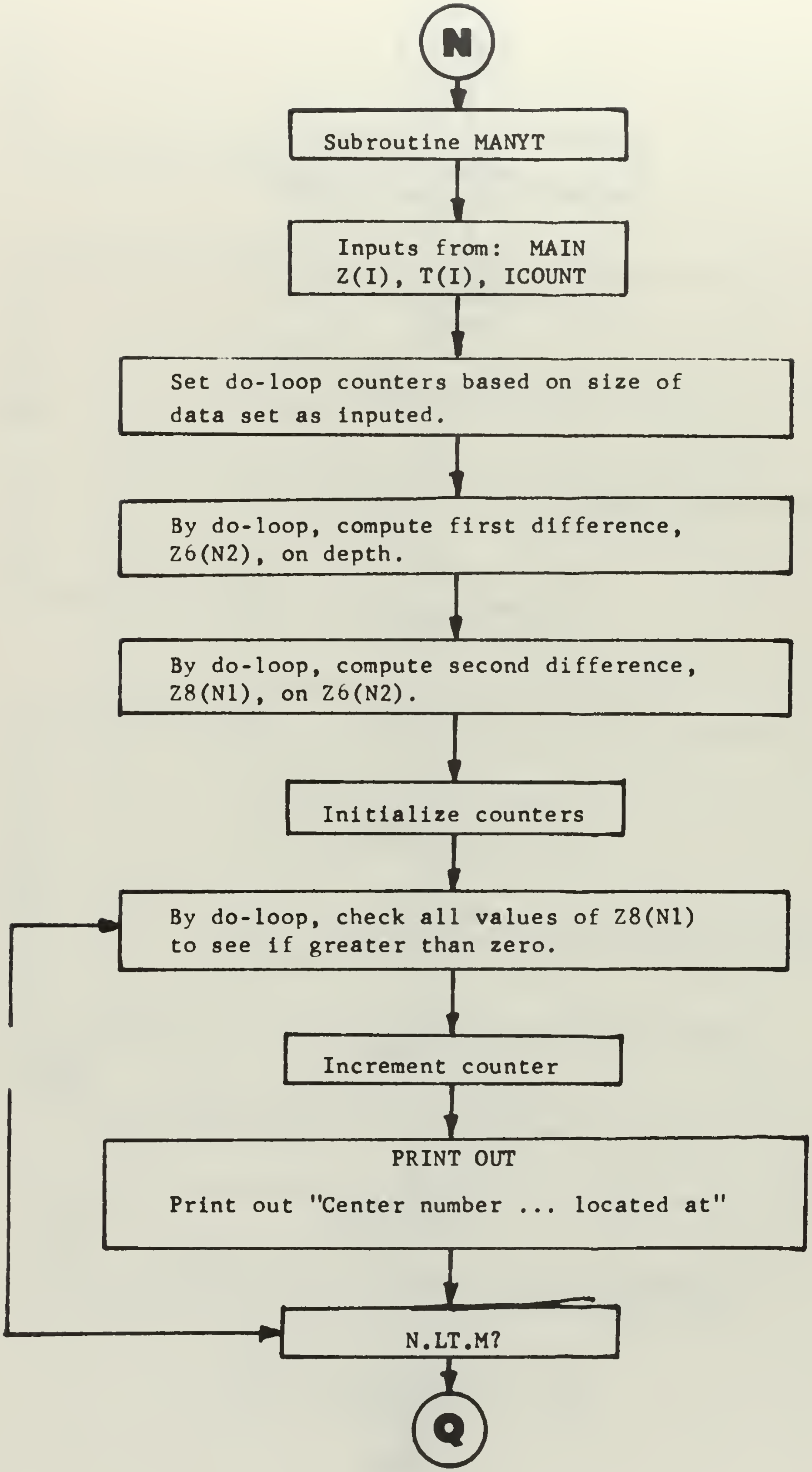

H
Subroutine PRINT5
Inputs from: INVERS
TMIN, ZMIN
PRINT OUT
Print out, "Minimum temperature in temperature inversion" and "Minimum temperature found at depth."
RETURN

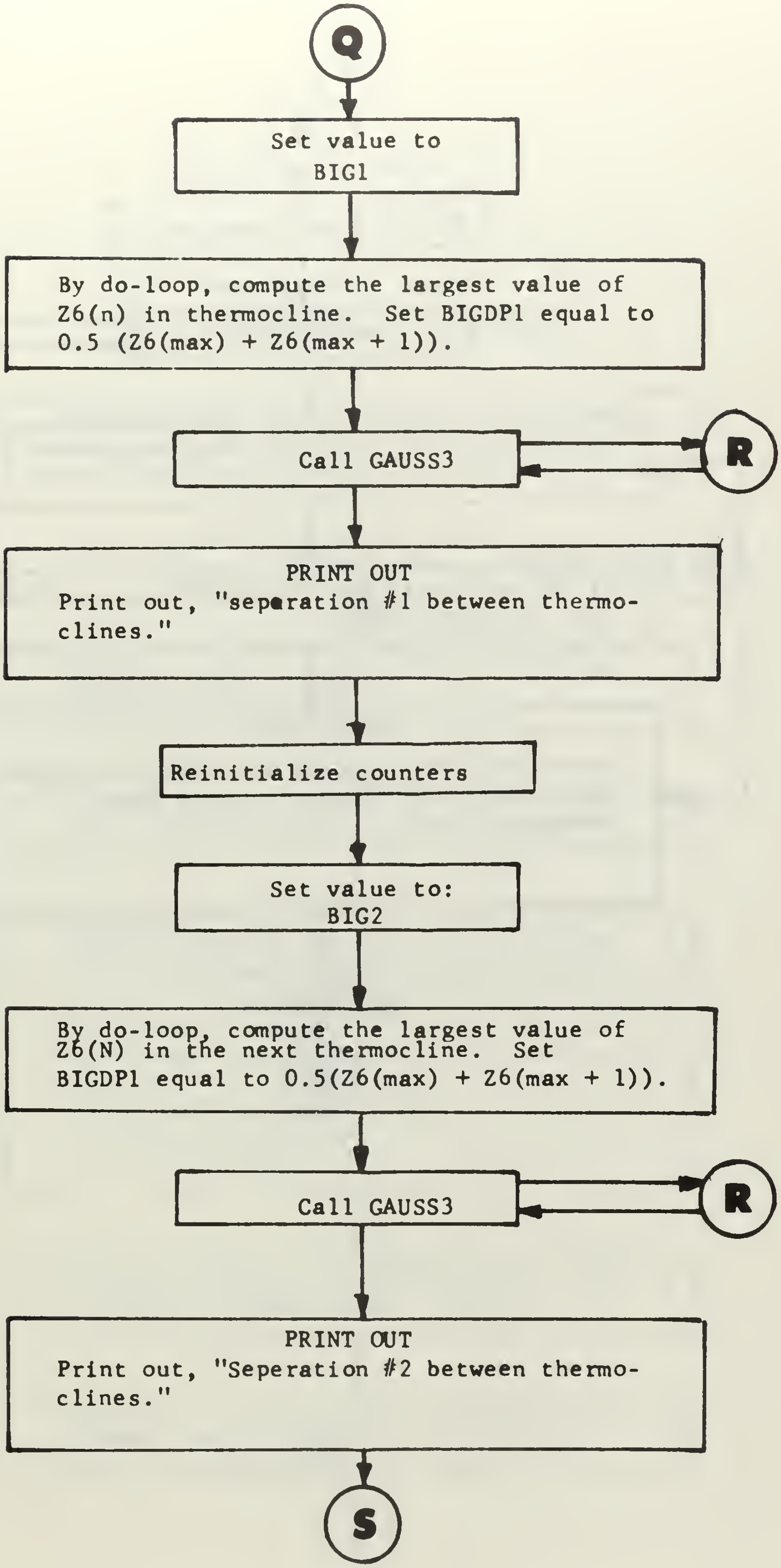

J
Subroutine PRINT6
Inputs from: INVERS
ZUPP, TUPP
Print out, "Spacial magnitude of temperature inversion" and "Thermal magnitude of temperature inversion."
RETURN

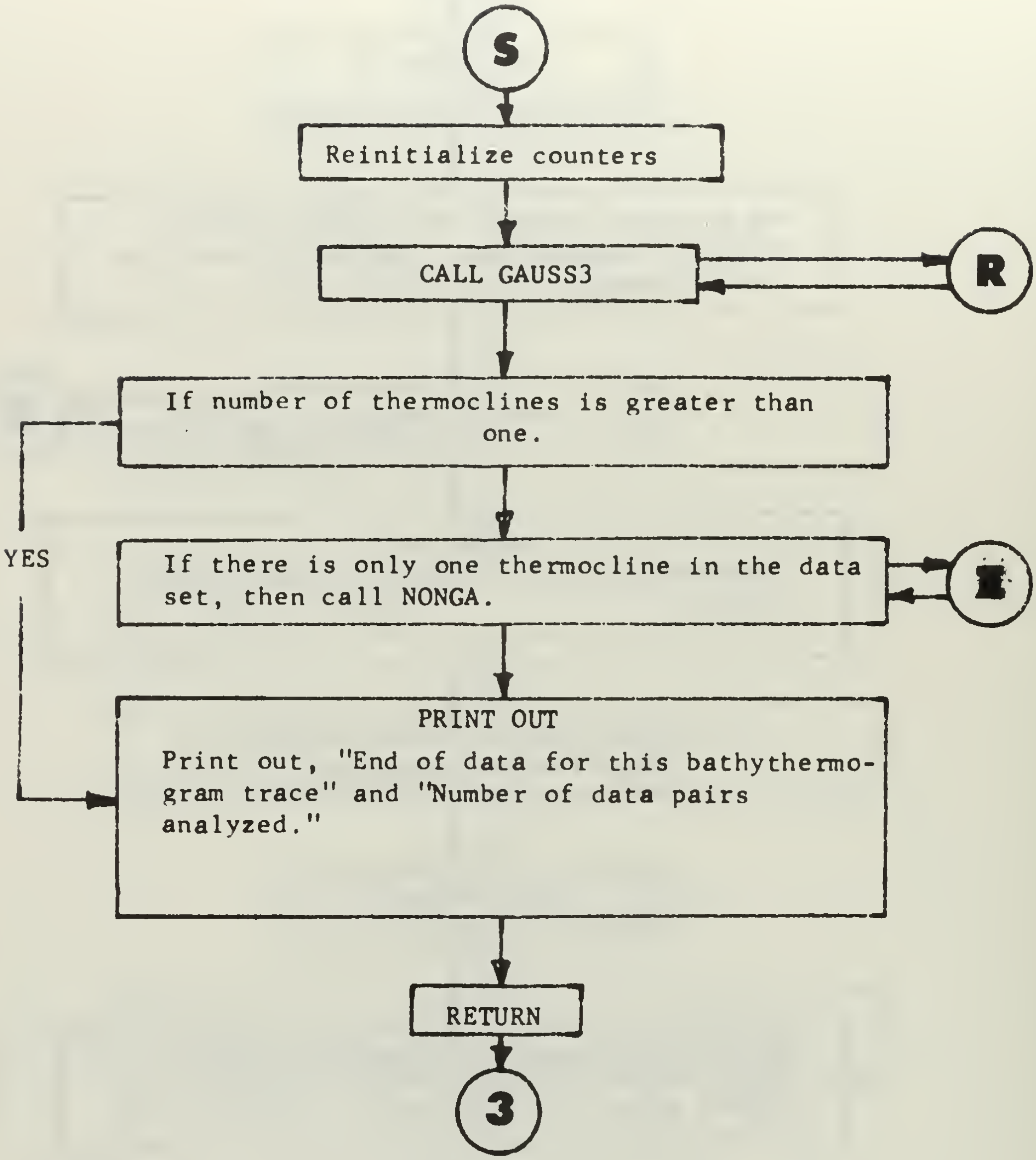

K
Subroutine TRANS
Inputs from: MAIN
Z(I), T(I), ICOUNT
Set do-loop counters, based on size of data set, ICOUNT.
Bydo-loop compute first difference, Z6(N), on depth.
By do-loop, compute second difference, Z7(I41), on Z6(N).
By loop, check sign of second difference to see if it is greater than zero.
YES
PRINT OUT
Print out, "Beginning of first transient"
NN.LE.M
YES
CONTINUE
NN.LE.M
YES
L

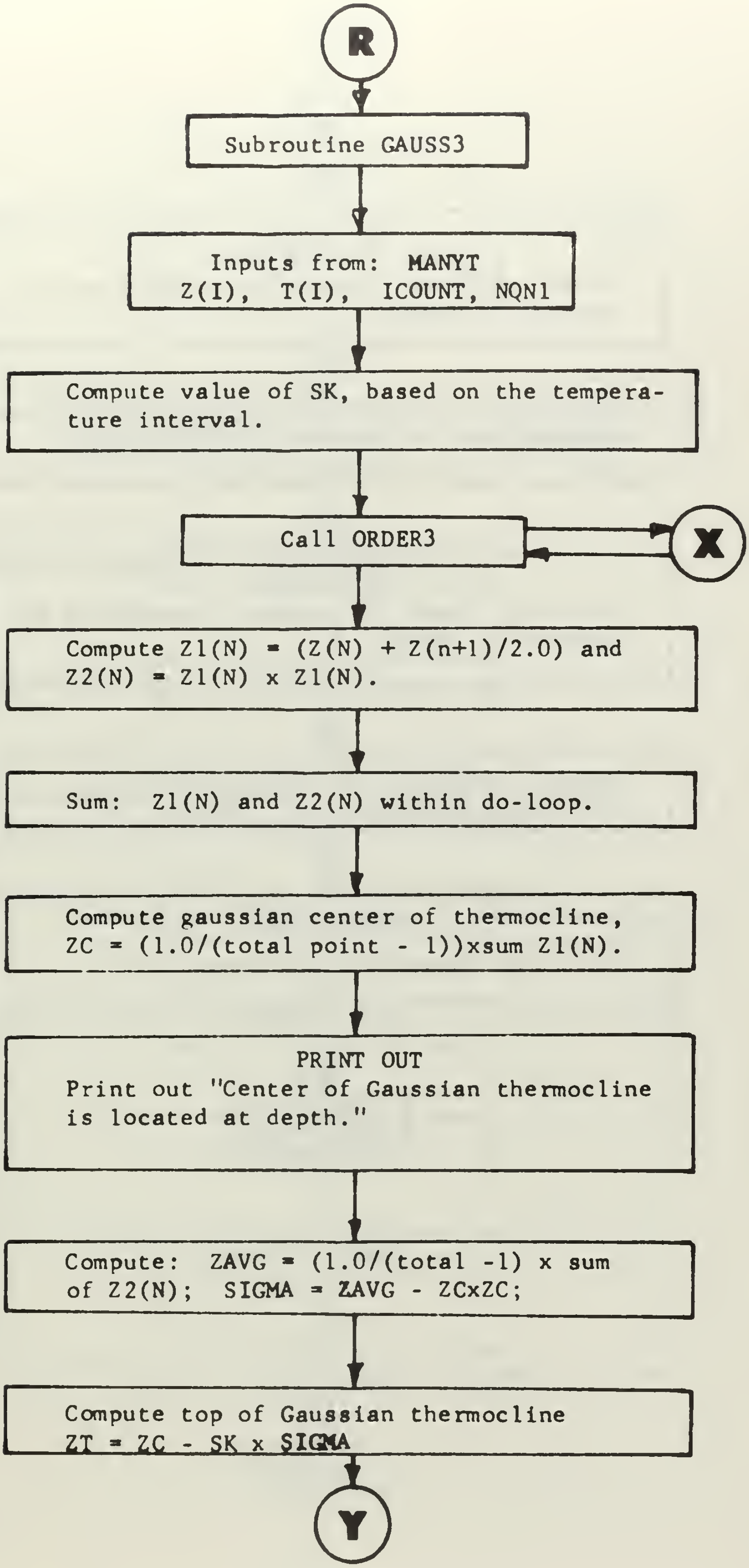

L
Increment NN
Z7(NN).gt.0?
Increment NN
NN.LE.M?
YES
YES
Increment NN
Z7(NN).LT.0?
INCREMENT NN
NN.LE.M?
YES
YES
PRINT OUT
Print out, "End of transient."
PRINT OUT
Print out, "Beginning of next transient"
NN.LE.M?
M


M
RETURN
2


N
Subroutine MANYT
Inputs from: MAIN
Z(I), T(I), ICOUNT
Set do-loop counters based on size of data set as inputed.
By do-loop, compute first difference, Z6(N2), on depth.
By do-loop, compute second difference, Z8(N1), on Z6(N2).
Initialize counters
By do-loop, check all values of Z8(N1) to see if greater than zero.
Increment counter
PRINT OUT
Print out "Center number ... located at"
N.LT.M?
Q


Q
Set value to BIG1
By do-loop, compute the largest value of Z6(n) in thermocline. Set BIGDP1 equal to 0.5 (Z6(max) + Z6(max + 1)).
Call GAUSS3
R
PRINT OUT
Print out, "separation #1 between thermoclines."
Reinitialize counters
Set value to: BIG2
By do-loop, compute the largest value of Z6(N) in the next thermocline. Set BIGDP1 equal to 0.5(Z6(max) + Z6(max + 1)).
Call GAUSS3
R
PRINT OUT
Print out, "Seperation #2 between thermoclines."
S


S
Reinitialize counters
CALL GAUSS3
R
If number of thermoclines is greater than one.
YES
If there is only one thermocline in the data set, then call NONGA.
PRINT OUT
Print out, "End of data for this bathythermogram trace" and "Number of data pairs analyzed."
RETURN
3



Subroutine GAUSS3

Inputs from: MANYT
Z(I), T(I), ICOUNT, NQN1

Compute value of SK, based on the temperature interval.

Call ORDER3

Compute Z1(N) = (Z(N) + Z(n+1)/2.0) and
Z2(N) = Z1(N) x Z1(N).

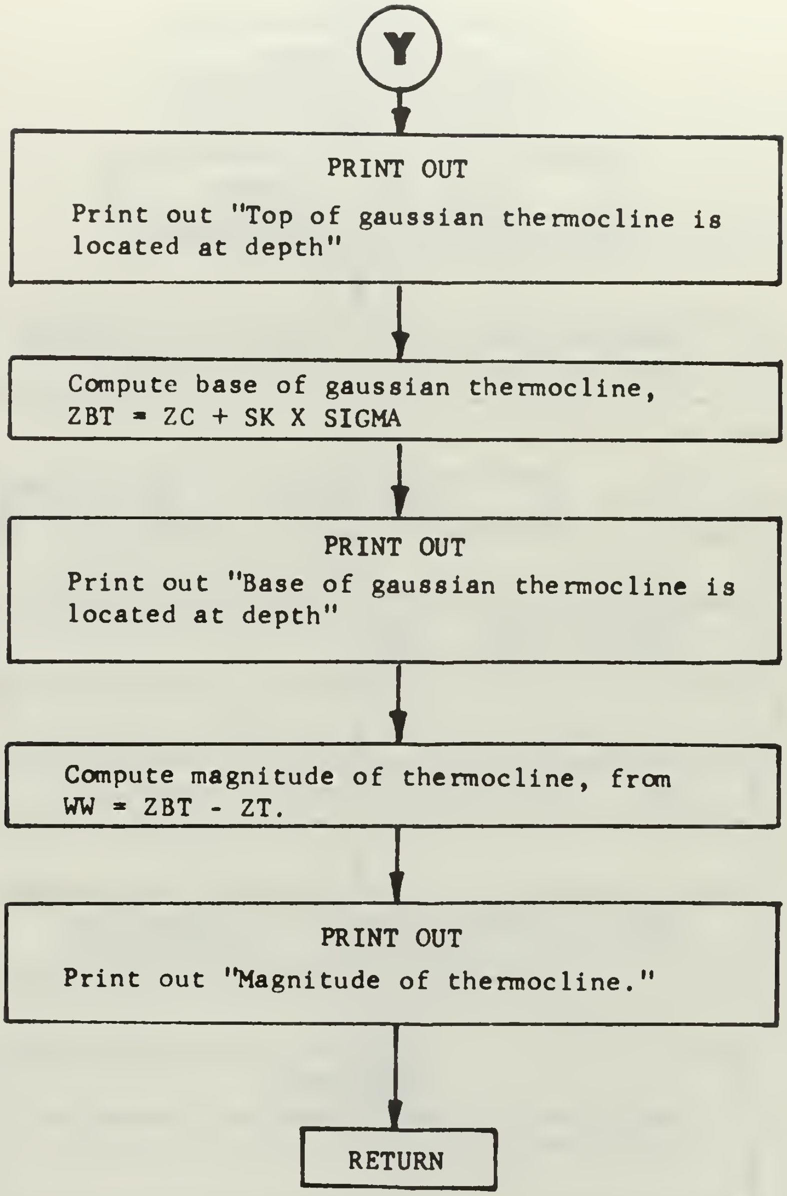
Sum: Z1(N) and Z2(N) within do-loop.

Compute gaussian center of thermocline,
ZC = (1.0/(total point - 1))xsum Z1(N).

PRINT OUT
Print out "Center of Gaussian thermocline is located at depth."

Compute: ZAVG = (1.0/(total -1) x sum of Z2(N); SIGMA = ZAVG - ZCxZC;

Compute top of Gaussian thermocline
ZT = ZC - SK x SIGMA



PRINT OUT

Print out "Top of gaussian thermocline is located at depth"

Compute base of gaussian thermocline, ZBT = ZC + SK X SIGMA

PRINT OUT

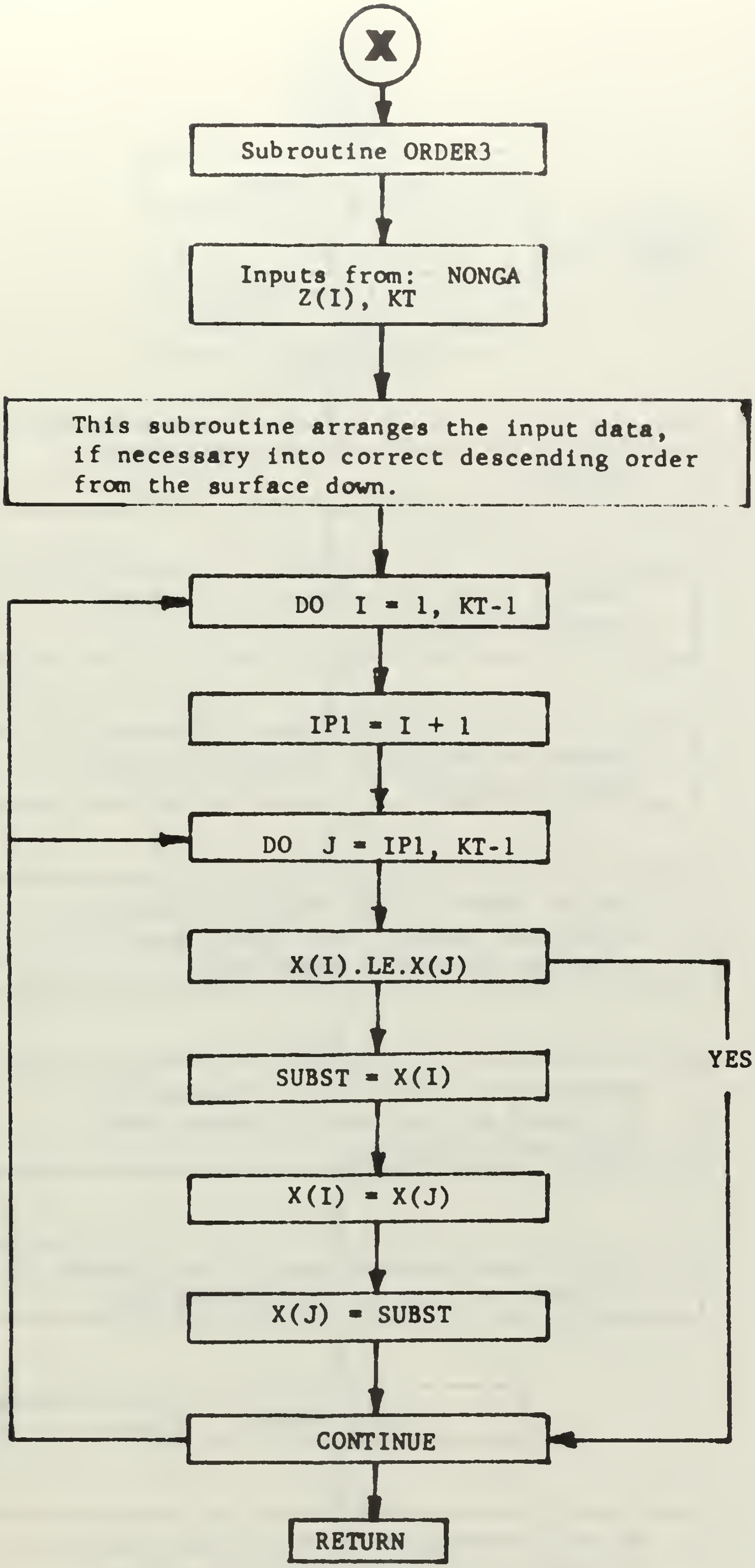
Print out "Base of gaussian thermocline is located at depth"

Compute magnitude of thermocline, from WW = ZBT - ZT.

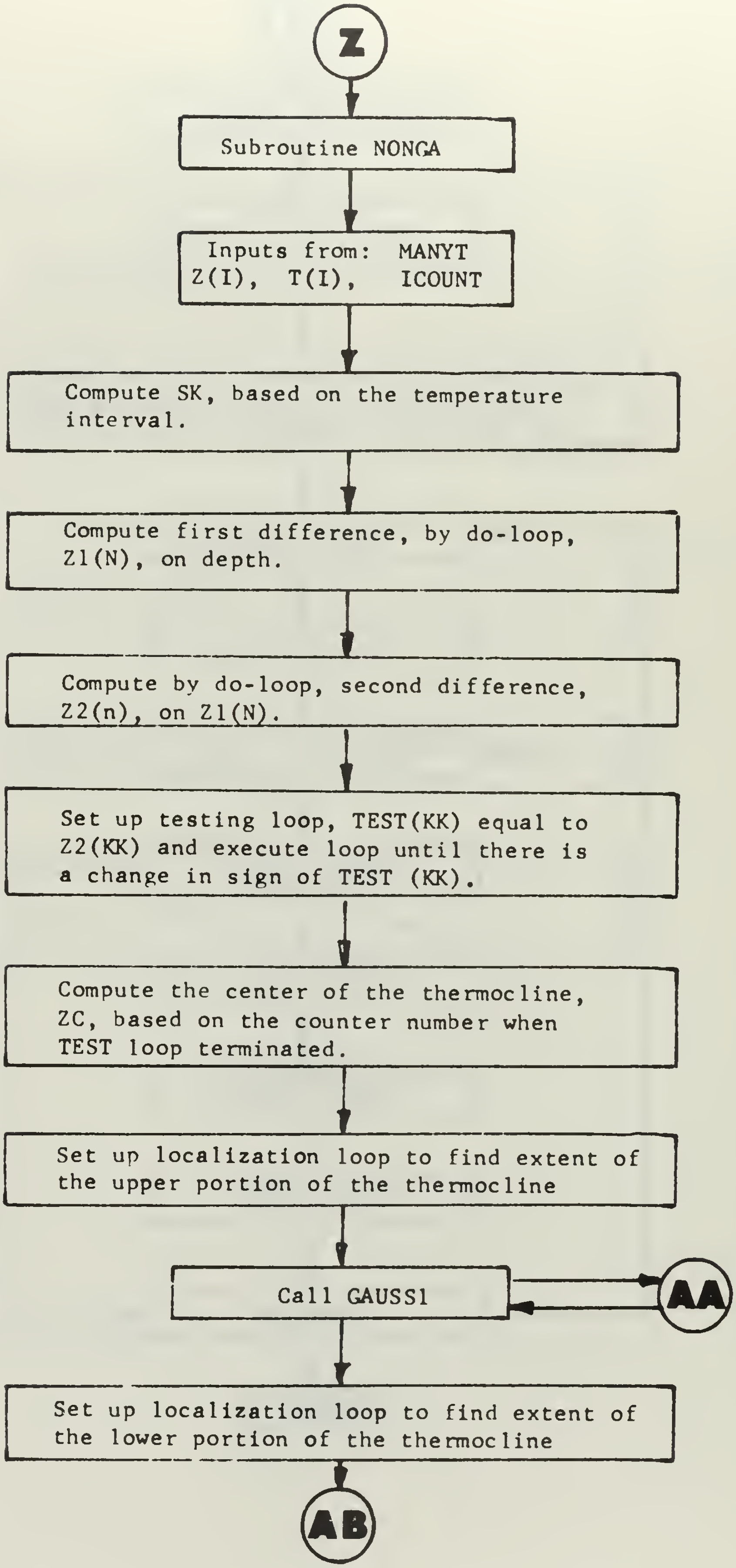
PRINT OUT

Print out "Magnitude of thermocline."

RETURN



This subroutine arranges the input data, if necessary into correct descending order from the surface down.



Subroutine NONGA

Inputs from: MANYT
Z(I), T(I), ICOUNT

Compute SK, based on the temperature interval.

Compute first difference, by do-loop, Z1(N), on depth.

Compute by do-loop, second difference, Z2(n), on Z1(N).

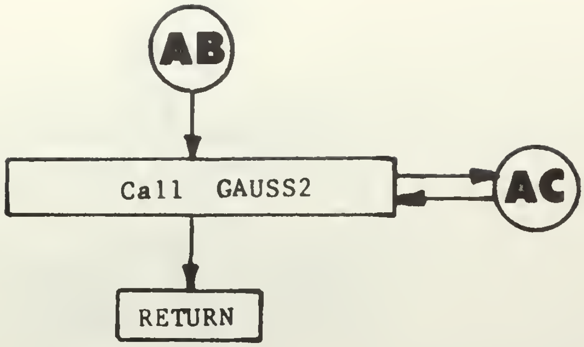
Set up testing loop, TEST(KK) equal to Z2(KK) and execute loop until there is a change in sign of TEST (KK).

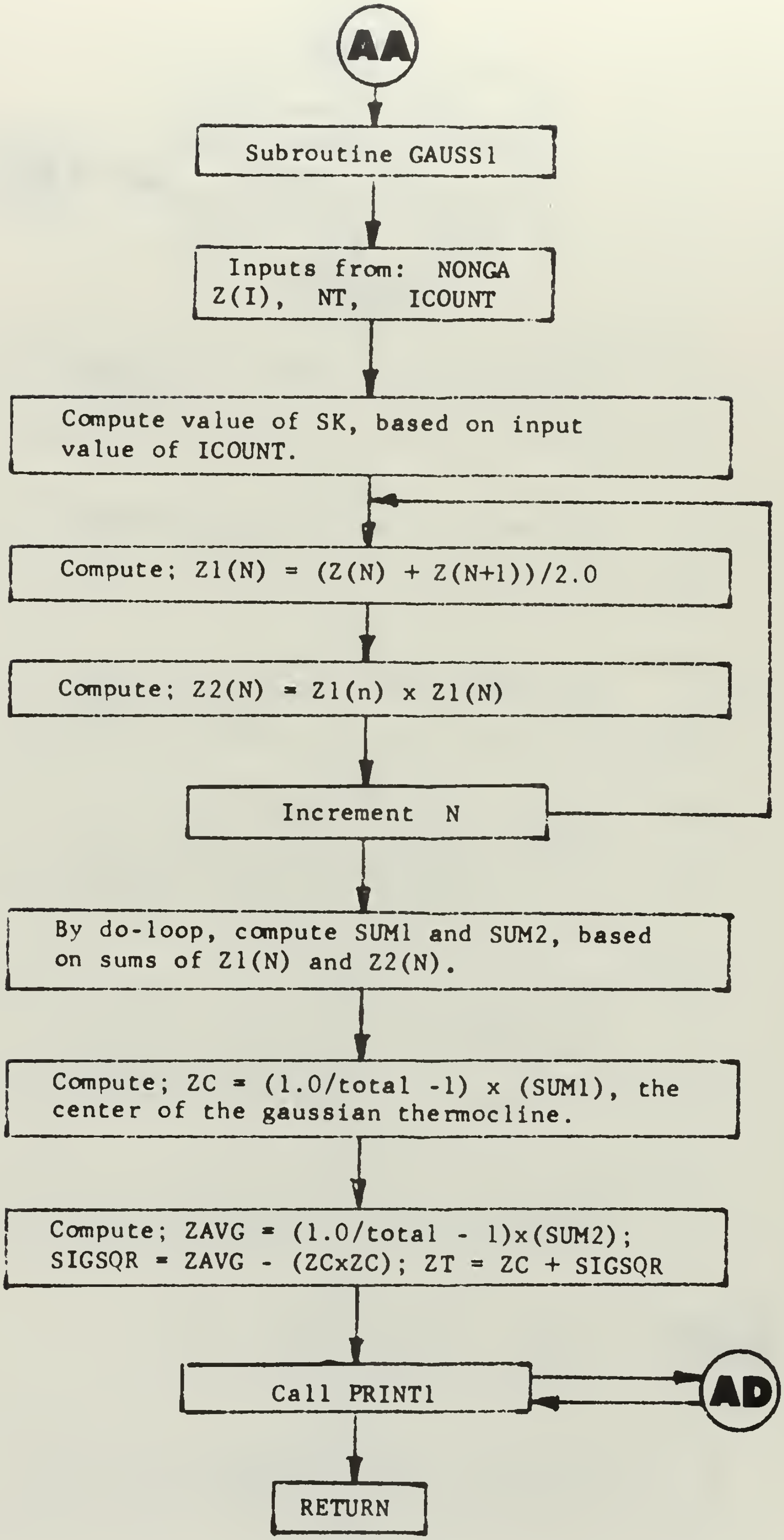
Compute the center of the thermocline, ZC, based on the counter number when TEST loop terminated.

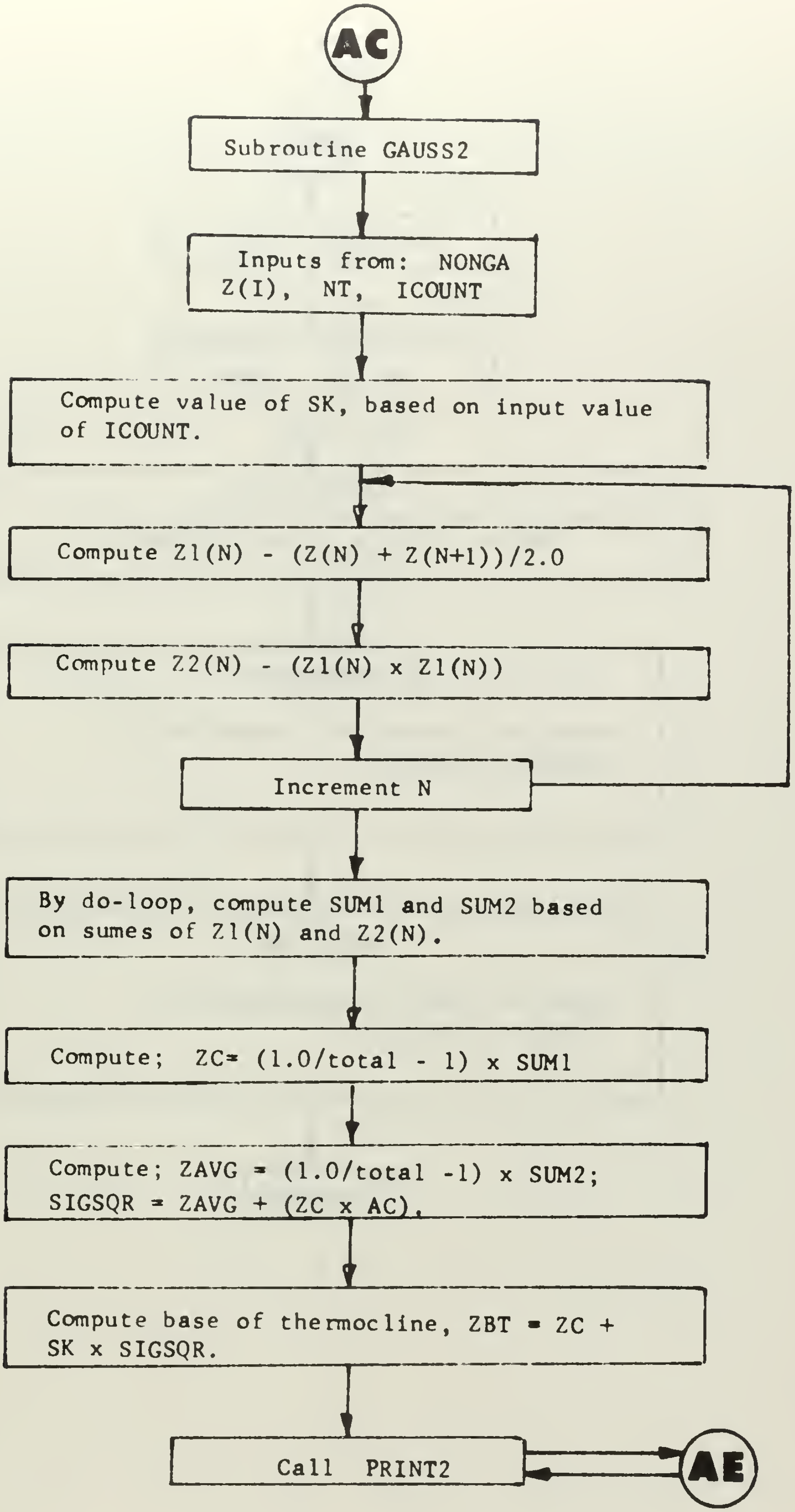
Set up localization loop to find extent of the upper portion of the thermocline

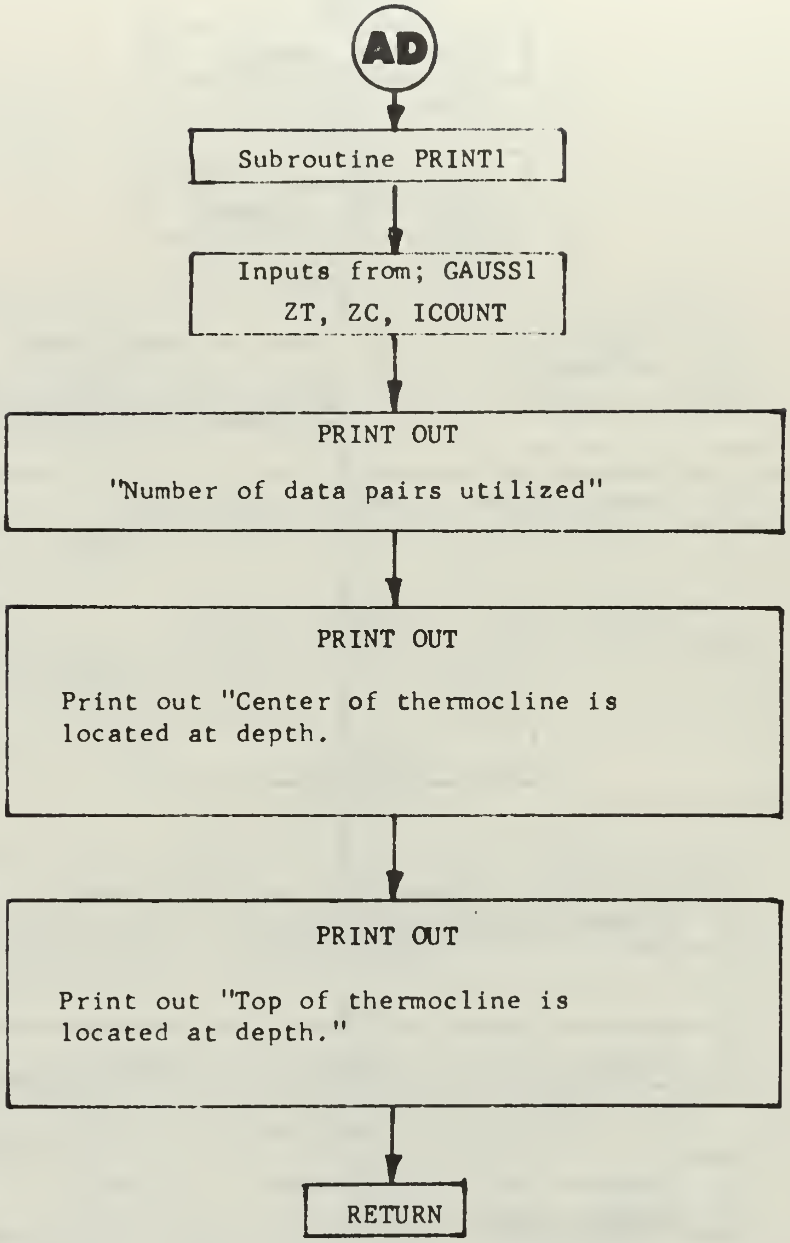
Call GAUSS1

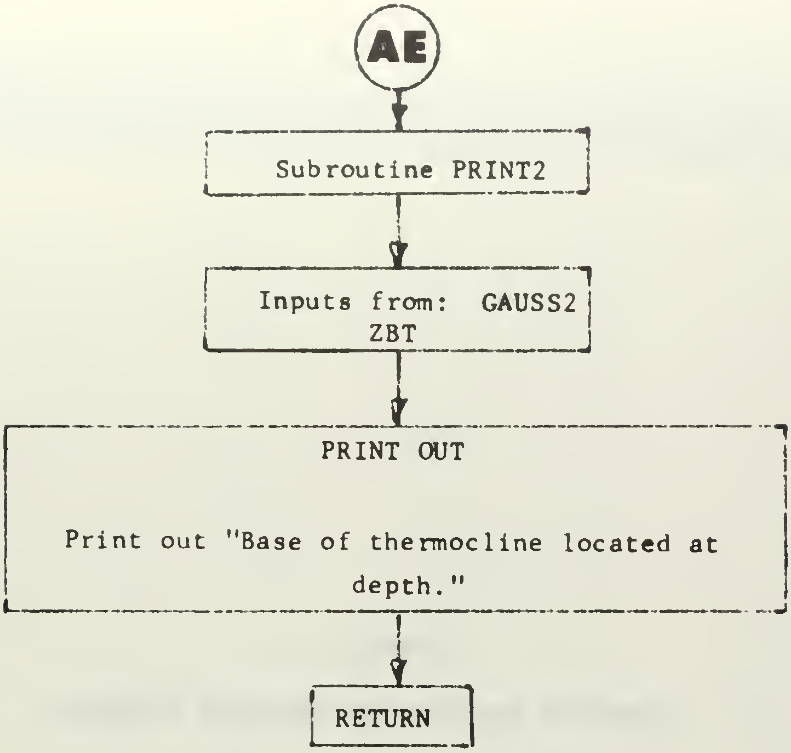
Set up localization loop to find extent of the lower portion of the thermocline


AB
Call GAUSS2
AC
RETURN


AA
Subroutine GAUSS1
Inputs from: NONGA
Z(I), NT, ICOUNT
Compute value of SK, based on input value of ICOUNT.
Compute; Z1(N) = (Z(N) + Z(N+1))/2.0
Compute; Z2(N) = Z1(n) x Z1(N)
Increment N
By do-loop, compute SUM1 and SUM2, based on sums of Z1(N) and Z2(N).
Compute; ZC = (1.0/total -1) x (SUM1), the center of the gaussian thermocline.
Compute; ZAVG = (1.0/total - 1)x(SUM2);
SIGSQR = ZAVG - (ZCxZC); ZT = ZC + SIGSQR
Call PRINT1
AD
RETURN


AC
Subroutine GAUSS2
Inputs from: NONGA
Z(I), NT, ICOUNT
Compute value of SK, based on input value of ICOUNT.
Compute Z1(N) - (Z(N) + Z(N+1))/2.0
Compute Z2(N) - (Z1(N) x Z1(N))
Increment N
By do-loop, compute SUM1 and SUM2 based on sumes of Z1(N) and Z2(N).
Compute; ZC= (1.0/total - 1) x SUM1
Compute; ZAVG = (1.0/total -1) x SUM2;
SIGSQR = ZAVG + (ZC x AC).
Compute base of thermocline, ZBT = ZC + SK x SIGSQR.
Call PRINT2
AE


AD
Subroutine PRINT1
Inputs from; GAUSS1
ZT, ZC, ICOUNT
PRINT OUT
"Number of data pairs utilized"
PRINT OUT
Print out "Center of thermocline is located at depth.
PRINT OUT
Print out "Top of thermocline is located at depth."
RETURN


AE
Subroutine PRINT2
Inputs from: GAUSS2
ZBT
PRINT OUT
Print out "Base of thermocline located at depth."
RETURN

APPENDIX II

OBJECTIVE THERMOCLINE ANALYSIS PROGRAM

```
C                                                                       0002
//  EXEC   FORTCLG,REGION.GO=130K,TIME.GO=3                             0000
//FORT.SYSIN DD *                                                       0001
C                                                                       0003
C                                                                       0004
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```
C
C
C     GENERAL INFORMATION CONCERNING MAIN PROGRAM'S FUNCTION:
C
C           THIS SEGMENT, TITLED "MAIN", IS DESIGNED TO READ ALL THE
C           DATA, BOTH TRACE AND POSITIONAL, AND BY THE UTILIZATION OF
C           CONTROL CARDS DISCRIMINATE BETWEEN THERMAL TRACES.  AFTER
C           READING IN EACH TRACE, AN INVESTIGATION INTO THE POSSIBLE
C           EXISTENCE OF "INVERSIONS" AND "TRANSIENTS" IS PERFORMED.
C           IF NEITHER EXISTS, THIS PROGRAM WILL INVESTIGATE EACH SINGLE
C           OR MULTIPLE THERMOCLINES THAT MAY EXIST (UP TO AND INCLUDING
C           THREE MAJOR THERMOCLINES PER TRACE).
C
C
C     METHOD OF ANALYSIS:
C
C           THE "MAIN" PROGRAM TAKES THE DATA AND CHECKS EACH TEMPERA-
C           TURE IN THE BT TRACE AND COMPARES IT TO EVERY OTHER TEMP-
C           ERATURE IN THAT TRACE.  IF A DOUBLE, OR GREATER, OCCURENCE
C           OF A GIVEN TEMPERATURE EXISTS, THEN THE SYSTEM LOOKS INTO
C           THE POSSIBILITY OF AN INVERSION EXISTING.  IF NO DOUBLE
C           VALUES OF TEMPERATURE EXIST, THEN THE TEMPERATURE INTERVAL
C           DELTA-T IS INVESTIGATED.  IF THE INTERVAL IS LESS THAN 0.2
C           DEGREES AN IDENTIFICATION OF TRANSIENTS, IF ANY EXIST, IS
C           UNDERTAKEN.  ONCE THE PREVIOUS FEATURES HAVE BEEN IDENTI-
C           FIED, THE PROGRAM SHIFTS INTO ANOTHER ROUTINE TO IDENTIFY
C           THE PROPERTIES OF THE THERMOCLINE(S).
C
C
C     INPUTS TO THE MAIN PROGRAM:
C
C           THE FOLLOWING ARE THE BT TRACE DATA INPUTS:
C
C                T(I)    -  INDIVIDUAL TEMPERATURE READINGS IN DEGREES
C                           CELCIUS OR FARENHEIT.
C
C                Z(I)    -  DEPTH READINGS, CORRESPONDING TO T(I)'S
C                           ABOVE, IN METERS OR FEET.
C
C           THE FOLLOWING ARE THE POSITIONAL DATA (SEE USER'S NOTE-3
C           BELOW):
C
C                LAT     -  WHOLE DEGREES OF LATITUDE
C
C                XLAT    -  MINUTES AND HUNDREDTHS OF MINUTES OF DEGREE
C                           OF LATITUDE.
C
C                LONG    -  WHOLE DEGREES OF LONGITUDE
```

```
C              ORDER2 - INSURES CORRECT, SURFACE DOWNWARD, ORDER.
C
C              PRINT3 - PRINTS OUT DEPTH OF TOP OF INVERSION
C
C              PRINT4 - PRINTS OUT DEPTH OF BASE OF INVERSION
C
C              PRINT5 - PRINTS OUT MINIMUM TEMPERATURE AND ITS DEPTH.
C
C              PRINT6 - PRINTS OUT SPACIAL AND THERMAL MAGNITUDE OF THE
C                       INVERSION.
C
C
C
C
C
      DIMENSION Z(30), T(30), A(30), B(30), C(30), D(30),E(30), F(30)
      DIMENSION G(30), P(30), R(30), TEST1(30) ,TEST2(30)
      WRITE(6,3030)
 3030 FORMAT(//3X,'COMPARE THE FOLLOWING DATA TO INSURE RIGHT DATA FLOW
     * FROM MAIN TO SUB-ROUTINE',//)
      WRITE(6,3031) (Z(I), T(I),I=1,ICOUNT)
 3031 FORMAT(//3X,2F10.3,/)
      IF((T(1)-T(2)).GE.1.0) SK=1.30000
      IF((T(1)-T(2)).LE.0.5) SK= 1.470000
      III = ICOUNT
      ICO1 = ICOUNT - 1
      ICO2 = ICOUNT - 2
C
C     LOOKS AT FIRST SLOPE CHANGE BELOW SURFACE AND FINDS ITS END BASED
C     ON SIGN CHANGE OF FIRST DIFFERENCE, B(N).
C
      CALL ORDER2(Z,T,SK,ICOUNT,III                    )
      DO 79 NN= 1, ICO1
      A(NN) = T(NN+1) - T(NN)
   79 CONTINUE
      DO 77 M=1,ICO1
      IF(A(M) - 0.0) 77, 77, 178
   77 CONTINUE
      IF(A(1).LT.0.0) GO  TO 78
  178 DO 101 N=1,ICO1
      NCOUNT = N
C     WRITE(6,107) NCOUNT
C 107 FORMAT(/5X,'NCOUNT = ', I2,/)
      A(N) = T(N+1) - T(N)
      IF(A(N).GT.0.0) GO TO 102
      B(N) = Z(N+1) - Z(N)
C     WRITE(6,3003) B(N)
C3003 FORMAT(/3X,F10.3,/)
```

```
7007 CALL MANYT(Z,T,ICOUNT,I     )
7010 WRITE(6,3) NBT
   3 FORMAT(//////3X,' COMPLETION OF ALL INVESTIGATIONS INTO BATHYMETRI
    *C FEATURES FOR BATHYTHERMOGRAPH TRACE NUMBER, ',I3,///////////)
     NBT = NBT + 1
     IF(ICOUNT.GT.0) GO TO 7004
7006 STOP
     END


     SUBROUTINE INVERS(Z,T,ICOUNT     )
C
C
C    GENERAL INFORMATION CONCERNING THE INVERSION SUBROUTINE:
C
C
C          THIS SEGMENT, ENTITLED "INVERS", WHEN CALLED FROM THE "MAIN"
C          SEGMENT, USES NON-GAUSSIAN ANALYSIS TO IDENTIFY THE TOP AND
C          BASE OF THE THERMOCLINE, MINIMUM TEMPERATURE, AND SPACIAL
C          AND THERMAL MAGNITUDE OF THE INVERSION.
C
C
C    METHOD OF ANALYSIS:
C
C          THE "INVERS" SUBROUTINE USES FIRST AND SECOND DIFFERENCES
C          TO LOOK AT THE SIGN CHANGES IN THE TRACE SLOPE TO FIND THE
C          TOP AND BASE OF THE INVERSION AND NUMERICAL METHODS TO DEFINE
C          THE OTHER FEATURES.
C
C
C    INPUTS FROM "MAIN" PROGRAM:
C
C          T(I)   - TEMPERATURES AT CHOSEN DEPTHS
C
C          Z(I)   - DEPTHS CORRESPONDING TO THE T(I)'S ABOVE.
C
C          ICOUNT - INTERNAL COUNTER INDICATING THE TOTAL NUMBER OF
C                   DATA PAIRS FROM THE "MAIN" PROGRAM.
C
     A4=2
C
C    SUBROUTINES CALLED FROM "INVERS":
C
C          ORDER1 - REARRANGES VALUES FOR COMPUTATION FOR SECOND SLOPE
C                   CHANGE (INTERNAL PROCEDURE).
C
```

```
      IF(T(I).EQ.0.0.AND.Z(I).GT.0.0) GO TO 7014
      IF(T(I).EQ.0.0.AND.Z(I).EQ.0.0) GO TO 7006
      ICOUNT = ICOUNT + 1
      I=I+1
      IF(ICOUNT.GE.1) GO TO 7001
C7005 DO 1 K=1,ICOUNT
C     WRITE(6,2) T(K), Z(K)
C   2 FORMAT (//3X, 2F10.3,//)
C   1 CONTINUE
 7014 READ(5,1) LAT,XLAT,LONG,YLONG,QUAD1,QUAD2,DATE1,DATE2,DATE3,TIME,
     * SERIAL
    1 FORMAT(I3,F6.2,I4,F6.2,2I2,3I3,I7,I8)
      CALL PRINT7(LAT,LONG,YLONG, QUAD1,QUAD2,DATE1,DATE2,DATE3,TIME,
     *XLAT,SERIAL)
C
C     TEST FOR REPEAT TEMPERATURES AND CALL INVERSION SUB-ROUTINE IF
C     THEY EXIST.
C
      DO 7008 J3J=1,ICOUNT
      DO 7008 I39=1,ICOUNT
      IF(J3J.EQ.I39) GO TO 7008
      IF(TINV(J3J).EQ.T(I39)) GO TO 7009
C     WRITE(6,4) TINV(J3J), T(I39)
C   4 FORMAT(//3X,2F7.1,/)
 7008 CONTINUE
      WRITE(6,6)
    6 FORMAT(//10X,'NO TEMPERATURE INVERSION EXISTS IN THIS TRACE',/)
      IF(ICOUNT.GT.0) GO TO 7012
 7009 CALL INVERS(Z,T,ICOUNT        )
      WRITE(6,8)
    8 FORMAT(//10X,'NO THERMAL TRANSIENTS EXIST IN THIS TRACE',/)
      WRITE(6,9)
    9 FORMAT(//10X,'NO MULTIPLE THERMOCLINES EXIST IN THIS TRACE',/)
      IF(ICOUNT.GT.0) GO TO 7010
 7012 DNKN = - 0.2
C
C     TEST TEMPERATURE INTERVAL TO SEE IF WORTHWHILE INVESTIGATING FOR
C     PRESENCE OF TRANSIENTS IN THERMAL STRUCTURE.
C
      IF((T(1)-T(2)).GE.0.2.OR.(T(1)-T(2)).LE.DNKN) GO TO 7013
      IF((T(2)-T(1)).LT.0.2) GO TO 7011
 7011 CALL TRANS(Z,T,ICOUNT    )
      IF(ICOUNT.GE.1) GO TO 7010
C
C     INVESTIGATE NATURE OF EXISTING THERMOCLINE(S).
C
 7013 WRITE(6,7)
    7 FORMAT(//10X,'NO THERMAL TRANSIENTS EXIST IN THIS TRACE',/)
```

```
C              #3 BELOW).  CONTROL CARD "1" IS USED FOR THIS PURPOSE, AND       0143
C              CONSISTS OF 0.0 SUBSTITUTED FOR "T" AND ANY NON-ZERO VALUE       0144
C              SUBSTITUTED FOR "Z".  CONTROL CARD "1" MUST FOLLOW THE LAST      0145
C              TRACE AND/OR POSITIONAL CARD USED IN EACH INDIVIDUAL TRACE.      0146
C                                                                               0147
C          2.  THE LAST CARD IN THE DATA DECK, IF USED, MUST BE CONTROL         0148
C              CARD "2", WHICH CONSISTS OF REPLACING BOTH "T" AND "Z" VALUE     0149
C              CARD "1" UTILIZED.                                               0150
C                                                                               0151
C          3.  POSITIONAL DATA CARDS ARE USED ONLY WHEN DESIRED.  IF YOU        0152
C              DO NOT DESIRE TO INCLUDE THIS INFORMATION THEN "PULL" CARDS      0153
C              (0200-0205  ) BEFORE USING PROGRAM, AND THEN DO NOT INSERT       0154
C              POSITIONAL DATA CARD BETWEEN LAST TRACE DATA CARD AND            0155
C              CONTROL CARD "1" FOR THAT TRACE(S).                              0156
C                                                                               0157
C          4.  THERMAL VARIATIONS SIMILAR TO A THERMOCLINE BUT WITH FEATURES    0158
C              ONLY DEFINABLE BY USING A TEMPERATURE DIFFERENTIAL OF ABOUT      0159
C              0.1 DEGREES IS WHAT THIS PROGRAM DEFINES AS A TRANSIENT.         0160
C                                                                               0161
C          5.  FOR EASE IN PROBLEM TRACING, SHOULD IT BECOME NECESSARY,         0162
C              THE "WRITE" STATEMENTS THAT ARE PRECEEDED BY "C" CAN HAVE        0163
C              THAT"C" REMOVED AND THEN BE 9EINSE9T5D T6 663LOW THE PROGRESS    0164
C              THAT THE PROGRAM AND ITS ROUTINES ARE FOLLOWING.                 0165
C                                                                               0166
C                                                                               0167
C                                                                               0168
C                                                                               0169
C                                                                               0170
C                                                                               0171
C                                                                               0172
C                                                                               0173
C                                                                               0174
C                                                                               0175
C                                                                               0176
      DIMENSION T(5000), Z(5000) , TINV(50)                                     0177
      INTEGER QUAD1, QUAD2, DATE1, DATE2, DATE3, TIME,SERIAL                    0178
      EQUIVALENCE (TINV(1), T(1))                                               0179
      NBT = 1                                                                   0180
 7004 I = 1                                                                     0181
      WRITE(6,5) NBT                                                            0182
    5 FORMAT('1',3X,'START OF INVESTIGATIONS INTO TRACE CHARACTERISTICS         0183
     * FORBATHYTHERMOGRAPH TRACE NUMBER ',I3,//////////)                        0184
      ICOUNT = 0                                                                0185
C                                                                               0186
C     READ DATA CARDS AND CHECK CONTROL CARDS TO LOCALIZE EACH TRACE.           0187
C                                                                               0188
 7001 READ(5,7000) T(I), Z(I)                                                   0189
 7000 FORMAT(2F10.0)                                                            0190
```

```
C
C                   YLONG   -  MINUTES AND HUNDREDTHS OF MINUTES OF DEGREE
C                              OF LONGITUDE.
C
C                   QUAD1   -  QUADRANT CODE FOR LATITUDE, WHERE QUAD1=1
C                              DEFINES NORTH LATITUDE AND QUAD1=2 DEFINES
C                              SOUTH LATITUDE.
C
C                   QUAD2   -  QUADRANT CODE FOR LONGITUDE, WHERE QUAD2=1
C                              DEFINES EAST LONGITUDE AND QUAD2=2 DEFINES
C                              WEST LONGITUDE.
C
C                   DATE1   -  CALENDAR DAY OF THE MONTH (1-31)
C
C                   DATE2   -  MONTH OF THE YEAR (1-12)
C
C                   DATE3   -  LAST TWO DIGITS OF THE YEAR.
C
C                   TIME    -  DAY AND HOUR, GREENWICH MEAN TIME, OF BATHY-
C                              THERMOGRAPH OR OCEANOGRAPHIC STATION.
C
C
C      DATA CARD FORMAT:
C
C             BT TRACE DATA CARDS:  FORMAT IS IN "FLOATING POINT" NOT-
C             ATION, WITH "T" LISTED FIRST FOLLOWED BY "Z" ON EACH CARD.
C             (READING FORMAT = 2F10.0)
C
C             POSITIONAL TRACE DATA:  FORMAT IS IN MIXED "INTEGER" AND
C             "FLOATING POINT" NOTATION, AND LISTED IN THE FOLLOWING
C             ORDER: LAT, XLAT, LONG, YLONG, QUAD1, QUAD2, DATE1, DATE2,
C             DATE3, TIME, AND SERIAL.
C
C
C      SUBROUTINES CALLED FROM "MAIN" ARE:
C
C             INVERS(Z,TICOUNT)      - INVERSION IDENTIFICATION
C
C             TRANS(Z,T,ICOUNT)      - TRANSIENT IDENTIFICATION
C
C             MANYT(Z,T,ICOUNT,I)    - THERMOCLINE ANLAYSIS
C
C
C      SPECIAL NOTES FOR THE USER:
C
C         1.  WHEN THE DATA INPUT IS FROM DATA CARDS, VICE MAGNETIC TAPE,
C             CONTROL CARDS MUST BE USED TO SEPERATE THE INDIVIDUAL
C             TRACES AND THEIR POSITIONAL INFORMATION, IF USED (SEE NOTE
  101 CONTINUE                                                             0331
C     WRITE(6,3004) NCOUNT                                                 0332
C3004 FORMAT(/3X,F10.3,/)                                                   0333
  102 IC03 = NCOUNT -2                                                     0334
C                                                                          0335
C     COMPUTES SECOND DIFFERENCE ON B(N).                                  0336
C                                                                          0337
      DO 110 L=1,IC03                                                      0338
      G(L)=B(L+1) - B(L)                                                   0339
C     WRITE(6,3005) G(L)                                                   0340
C3005 FORMAT(/3X,F10.3,/)                                                   0341
  110 CONTINUE                                                             0342
      KC01 = 0                                                             0343
      DO 300 KK=1,ICOUNT                                                   0345
      TEST1(KK) = G(KK)                                                    0346
      KC01=KC01+1                                                          0347
C     WRITE(6,347)                                                         0348
C 347 FORMAT(//3X 'TEST1 AND KC01' //)                                     0349
C     WRITE(6,3006) TEST1(KK), KC01                                        0350
C3006 FORMAT(/3X, F10.3, I5,/)                                              0351
      IF(TEST1(KK).GT.0.0) GO TO 301                                       0352
  300 CONTINUE                                                             0353
  301 KK1=KC01                                                             0356
C     WRITE(6,3007) KK1                                                    0357
C3007 FORMAT(/3X, I5,/)                                                     0358
      KN1=KK1+1                                                            0359
C                                                                          0360
C     DEFINES TOP OF INVERSION.                                            0361
C                                                                          0362
      ZC1 = Z(KN1)                                                         0363
      TEMP2= T(KN1)                                                        0364
      M = NCOUNT + 1                                                       0365
C     WRITE(6,108) M                                                       0366
C 108 FORMAT(/5X, 'M = ', I2,/)                                            0367
      MM = M + 1                                                           0368
      NNCO = M                                                             0369
C                                                                          0370
C     LOOKS AT NEXT SLOPE SEGMENT AND COMPUTES FIRST DIFFERENCE, D(I31).    0371
C                                                                          0372
      DO 103 I31=M,IC01                                                    0373
      C(I31) = T(I31) - T(I31 + 1)                                         0374
      IF(C(I31).GT.0.0) GO TO 104                                          0375
      D(I31) = Z(I31) - Z(I31 + 1)                                         0376
C     WRITE(6,3020) D(I31)                                                 0377
C3020 FORMAT(/3X, F10.3,/)                                                  0378
      JCOUNT = N                                                           0379
C     WRITE(6,3008) JCOUNT                                                 0380
C3008 FORMAT(/3X, I5,/)                                                     0381
```

```
      NNCO = NNCO + 1
C     WRITE(6,99) NNCO
C  99 FORMAT(//10X, 'NNCO = ', I3, //)
  103 CONTINUE
C 104 WRITE(6,3009) NNCO,M,NNCO,M,NNCO,M
C3009 FORMAT(/3X,6I5,/)
C
C     INVERTS ORDER OF DEPTHS FOR EASE IN CALCULATION.C
C
  104 CALL ORDER1(D,NNCO,M)
      NN1 = NNCO-3
C
C     COMPUTES SECOND DIFFERENCE ON D(I31).
C
      DO 111 I32=M,NN1
      P(I32) = D(I32) - D(I32 + 1)
C     WRITE(6,3010) P(I32)
C3010 FORMAT(/3X,F10.3,/)
  111 CONTINUE
C     WRITE(6,3011) JCOUNT
C3011 FORMAT(/3X, I5,/)
      K = JCOUNT + 1
C     WRITE(6,109) K
C 109 FORMAT(/5X, ' K = ', I2,/)
C
C     DEFINES SPACIAL MAGNITUDE OF INVERSION.
C
      ZUPP = Z(NNCO) - ZC1
C     WRITE(6,3012) ZUPP, Z(K), Z(NCOUNT), Z(NNCO), ZC1
C3012 FORMAT(////3X, 4F10.3,////)
C
C     LOOKS AT FIRST SLOPE IN INVERSION REGION AND COMPUTES FIRST
C     DIFFERENCE, F(I33).
C
      DO 105 I33=K,ICO1
      E(I33) = T(I33 + 1) - T(I33)
      F(I33) = Z(I33 + 1) - Z(I33)
C     WRITE(6,3014) F(I33)
C3014 FORMAT(/3X,F10.3,/)
  105 CONTINUE
C
C     COMPUTES SECOND DIFFERENCE ON F(I33).
C
      DO 112 I34=K,ICO2
      R(I34) = F(I34 + 1) - F(I34)
C     WRITE(6,3015) R(I34)
C3015 FORMAT(/3X,F10.3,/)
  112 CONTINUE
```

```
      KCO2 = NNCO - 1
      DO 500 I35=K,ICOUNT
      TEST2(I35) = R(I35)
      KCO2 = KCO2 + 1
C     WRITE(6,547)
C 547 FORMAT(//3X, 'TEST2 AND KCO2', //)
C     WRITE(6,3016) TEST2(I35), KCO2
C3016 FORMAT(/3X, F10.3, I5,/)
      IF(TEST2(I35).GT.0.0) GO TO 501
  500 CONTINUE
  501 KK2=KCO2
C     WRITE(6,3017) KK2
C3017 FORMAT(/3X,I5,/)
      KN2=KK2+1
C
C     DEFINES BASE OF THERMAL INVERSION.
C
      ZC2 =Z(NNCO)
C     WRITE(6,3033) ZC2,NNCO,ZC2,NNCO
C3033 FORMAT(////3X,F10.3,I6,F10.3,I6,/////)
C
C     DEFINES MINIMUM TEMPERZTURE AND ITS DEPTH AND THERMAL MAGNITUDE OF
C     INVERSION.
C
      ZMIN = Z(NCOUNT)
      TMIN = T(NCOUNT)
      TUPP= TEMP2 - TMIN
C
C     ELIMINATES POSSIBILITY OF A NEGATIVE INVERSION.
C
      IF(TMIN.GE.TEMP2) GO TO 78
      CALL PRINT3(ZC1)
      CALL PRINT4(ZC2)
      CALL PRINT5(TMIN,ZMIN)
      CALL PRINT6(ZUPP,TUPP)
   78 RETURN
      END
      SUBROUTINE PRINT3(ZC1)
C
C
C     GENERAL INFORMATION CONCERNING THE PRINT3 SUBROUTINE:
C
C
C           THIS SEGMENT, ENTITLED "PRINT3", IS CALLED FROM "INVERS" TO
C           PRINT OUT THE LOCATION OF THE TOP OF THE  TEMPERATURE
C           INVERSION.
C
C
C     INPUTS FROM "INVERS" SUBROUTINE:
C
C           ZC1    - DEPTH OF TOP OF INVERSION.
C
C
C
C
C
      WRITE(6,3000)
 3000 FORMAT(//10X,'THE FOLLOWING INDICATES THE COMPUTED TOP OF THE TEMP
     *ERATURE INVERSION, BY NON-GAUSSIAN METHODS:')
      WRITE(6,3001) ZC1
 3001 FORMAT(//18X,'TEMPERATURE INVERSION TOP LOCATED AT DEPTH . . . . '
     *,F5.1)
      RETURN
      END


      SUBROUTINE PRINT4(ZC2)
C
C
C     GENERAL INFORMATION CONCERNING THE PRINT4 SUBROUTINE:
C
C           THIS SEGMENT, ENTITLED "PRINT4", IS CALLED FROM "INVERS" TO
C           PRINT OUT THE LOCATION OF THE BASE OF THE TEMPERATURE
C           INVERSION.
C
C
C     INPUTS FROM "INVERS" SUBROUTINE:
C
C           ZC2    - DEPTH OF BASE OF THE INVERSION.
C
C
C
      WRITE(6,4000)
 4000 FORMAT(//10X,'THE FOLLOWING INDICATES THE COMPUTED BASE OF THE TEM-
     *PERATURE INVERSION',/,10X,'BY NON GAUSSIAN METHODS:')
      WRITE(6,4001) ZC2
 4001 FORMAT(//18X,'TEMPERATURE INVERSION BASE LOCATED AT DEPTH  . . . '
     * ,F5.1)
      RETURN
      END



      SUBROUTINE PRINT5(TMIN, ZMIN)
C
C     GENERAL INFORMATION CONCERNING THE PRINT5 SUBROUTINE:
C
C
C           THIS SEGMENT, ENTITLED "PRINT5", IS CALLED FROM "INVERS" TO
C           PRINT OUT THE LOCATION OF THE MINIMUM TEMPERATURE AND ITS
C           DEPTH.
C
C
C     INPUTS FROM "INVERS" SUBROUTINE:
C
C           TMIN  - MINIMUM TEMPERATURE.
C
C           ZMIN  - DEPTH OF  MINIMUM TEMPERATURE.
C
C
C
      WRITE(6,5000)
 5000 FORMAT(//10X,'THE FOLLOWING FIGURES DEFINE THE MINIMUM TEMPERATURE
     * OF THE TEMPERATUR',/,10X,'INVERSION:')
      WRITE(6,5001) TMIN, ZMIN
 5001 FORMAT(//18X,'MINIMUM TEMPERATURE  . . . . . . . . . . . . . . . . '
     *,F5.1,/,18X,' DEPTH OF MINIMUM TEMPERATURE . . . . . . . . . . . . '
     * ,F5.1,/)
      RETURN
      END
      SUBROUTINE PRINT6(ZUPP,TUPP)
C
C
C     GENERAL INFORMATION CONCERNING THE PRINT6 SUBROUTINE:
C
C           THIS SEGMENT, ENTITLED "PRINT6", IS CALLED FROM "INVERS" TO
C           PRINT OUT THE THERMAL AND SPACIAL MAGNITUDE OF THE TEMPERA-
C           TURE INVERSION
C
C
C     INPUTS FROM "INVERS" SUBROUTINE:
C
C           TUPP  - THERMAL MAGNITUDE OF INVERSION.
C
C           ZUPP  - SPACIAL MAGNITUDE OF INVERSION.
C
C
C
      WRITE(6,6000)
 6000 FORMAT(//T10,'THE FOLLOWING FIGURES DENOTE THE TEMPERATURE AND',
     */,T10,'SPACIAL MAGNITUDE OF THE TEMPERATURE INVERSION',////)
      WRITE(6,6001) TUPP, ZUPP
 6001 FORMAT(//18X,'THERMAL MAGNITUDE OF INVERSION . . . . . . . . . . '
     *,F5.1,//18X, 'SPACIAL MAGNITUDE OF INVERSION . . . . . . . . . . '
     * ,F5.1)
      RETURN
      END
C


      SUBROUTINE ORDER1( X, III, M)
C
C
C     GENERAL INFORMATION CONCERNING THE ORDER1 SUBROUTINE:
C
C           THIS SUBROUTINE REORDERS DATA WITHIN THE SECOND SLOPE SEG-
C           MENT FOR EASE IN INTERNAL COMPUTATIONS.
C
C
C     INPUTS FROM "INVERS" SUBROUTINE:
C
C           D(I)  - DEPTHS TO BE REORDERED.
C
C           NNCO  - INTERNAL COUNTER TO START DO-LOOP.
C
C           M     - INTERNAL COUNTER TO END DO-LOOP.
```

```
C
C
C
C
      DIMENSION X(30)
      KT = III-2
      KTK = KT - 1
C     WRITE(6,3018) III,KT,KTK,M,III,KT,KTK,M
C3018 FORMAT(/3X, 8I5,/)
      DO 22 I = M,KTK
      IP2 = I + 1
C     WRITE(6,3019) IP2,IP2,IP2,IP2
C3019 FORMAT(/3X,4I5,/)
      DO 22 J=IP2,KTK
      IF(X(I).LE.X(J)) GO TO 22
      SUBST = X(I)
      X(I) = X(J)
      X(J) = SUBST
   22 CONTINUE
C     WRITE(6,50)
C  50 FORMAT(//10X,'ORDERED DEPTHS', //,T18,'DEPTH',//)
C     WRITE(6,41) (X(I), I=M,KT)
C  41 FORMAT(T10,F15.7,//)
      RETURN
      END


      SUBROUTINE ORDER2(X,T,SK,ICOUNT,III)
C
C
C     GENERAL INFORMATION CONCERNING THE ORDER2 SUBROUTINE:
C
C             THIS SUBROUTINE IS DESIGNED AS A SAFEGUARD TO INSURE ALL
C             DATA IS IN CORRECT ORDER FROM THE SURFACE DOWN, AN ORDER
C             WHICH IS A PREREQUISITE TO THE GAUSSIAN AND NON-GAUSSIAN
C             METHOD.
C
C
C     INPUTS FROM "INVERS" SUBROUTINE:
C
C             Z(I)  - DEPTHS FROM SURFACE DOWN.
C
C             T(I)  - TEMPERATURES FROM THE SURFACE DOWN.
C
C             SK    - STANDARD DEVIATION.
C
```

```
C              ICOUNT- INTERNAL COUNTER FOR DO-LOOPS
C
C              III    - INTERNAL COUNTER FOR DO-LOOPS.
C
C
C
C
C        GENERAL INFORMATION CONCERNING THE TRANSIENT SUBROUTINE:
C
      DIMENSION T(30), X(30)
      KT  = III
      KTK = KT-1
      DO 12 I=1,KTK
      IP1=I+1
      DO 12 J=IP1,KTK
      IF(X(I).LE.X(J)) GO TO 12
      SUBST = X(I)
      X(I) = X(J)
      X(J) = SUBST
      SUBST = T(I)
      T(I) = T(J)
      T(J) = SUBST
   12 CONTINUE
C     WRITE(6,40)
C  40 FORMAT(//10X, 'ORDERED DATA PAIRS FROM THE SURFACE', //, T18,'DEPT
C    *H', T30, 'TEMPERATURE', //)
C     WRITE(6,41) (X(I), T(I), I=1,KT)
C  41 FORMAT(T10, 2F15.7,//)
      RETURN
      END



      SUBROUTINE TRANS(Z,T,ICOUNT       )
C
C
C              THIS SEGMENT, ENTITLED "TRANS", WHEN CALLED BY THE "MAIN"
C              ROUTINE WILL LOOK AT THE THERMAL STRUCTURE TO DETERMINE THE
C              PRESENCE OF THERMAL TRANSIENTS (SEE NOTE #4 - "MAIN")
C
C
C        METHOD OF ANALYSIS:
C
C              THE "TRANS" SUBROUTINE USES A SIMPLE NON-GAUSSIAN FIRST AND
C              SECOND DIFFERENCE METHOD, USING CHANGES OF SIGN IN THE SLOPE
C              TO DEFINE EACH TRANSIENT.  THERE MUST BE A TEMPERATURE
C              DIFFERENTAIL NO LARGER THAN 0.2 DEGREES TO DEFINE A TRAN-
```

```
C               SIENT AS HEREIN DEFINED.
C
C
C       INPUTS FROM "MAIN" PROGRAM:
C
C               T(I)    - TEMPERATURE AT CHOSEN INTERV AL.
C
C               Z(I)    - DEPTHS CORRESPONDING TO T(I)'S ABOVE.
C
C               ICOUNT  - INTERNAL COUNTER INDICATING THE NUMBER OF DATA
C                         PAIRS USED.
C
      A5=1
C
C
C       SPECIAL NOTES FOR USFP:
C
C          1.   SEE NOTE #4 IN "MAIN" WRITE-UP.
C
C          2.   THIS SUBROUTINE HAS ITS OWN PRINTOUT STATEMENTS.
C
C
C
C
      DIMENSION Z(25), Z6(25), Z7(25)
      DIMENSION T(50)
      WRITE(6,4001)
 4001 FORMAT(//10X,'TRANSIENT DATA AS COMPUTED BY PROGRAM:',/)
      MM= ICOUNT
C     WRITE(6,4002) MM
C4002 FORMAT(/3X, I5,/)
      M=MM-2
      NM = MM - 1
C
C     COMPUTE FIRST DIFFERENCE.
C
      DO 50 N=1,NM
      Z6(N)= Z(N+1) - Z(N)
C     WRITE(6,4003) Z6(N)
C4003 FORMAT(/3X, F10.3,/)
   50 CONTINUE
C
C     COMPUTE SECOND DIFFERENCE.
C
      DO 51 I41=1,M
      Z7(I41) = Z6(I41 + 1) - Z6(I41)
C     WRITE(6,4004) Z7(I41)
C4004 FORMAT(/3X, F10.3,/)
```

```
   51 CONTINUE
      NN = 1
  186 IF(Z7(NN).GT.0.0) GO TO 185
C     WRITE(6,4005) Z7(NN)
C4005 FORMAT(/3X, F10.3,/)
      WRITE(6,1) Z(NN+1)
    1 FORMAT(//18X,'BEGINNING OF FIRST TRANSIENT AT ... ', F5.1)
      IF(NN.LE.M) GO TO 188
  185 NN = NN + 1
C     WRITE(6,4006) NN
C4006 FORMAT(/3X, I5,/)
      IF(NN.LE.M) GO TO 186
  188 NN = NN + 1
   14 IF(Z7(NN).LE.0.0) GO TO 13
      IF(Z7(NN).GT.0.0) GO TO 15
   13 NN = NN + 1
   20 IF(NN.GT.M) GO TO 23
      IF(NN.LE.M) GO TO 14
   15 NN = NN +1
   19 IF(NN.GT.M) GO TO 23
   17 IF(Z7(NN).GT.0.0) GO TO 16
      IF(Z7(NN).LT.0.0) GO TO 18
   16 NN = NN + 1
      IF(NN.GT.M) GO TO 23
      IF(NN.LE.M) GO TO 17
   18 WRITE(6,2) Z(NN)
    2 FORMAT(//18X,'END OF TRANSIENT  ......' ,F5.1)
      NZ1= NN+ 1
      WRITE(6,3) Z(NZ1)
    3 FORMAT(//18X,'BEGINNING OF THE NEXT TRANSIENT ...',F5.1)
      NN = NN + 1
      IF(NN.GT.M) GO TO 23
      IF(NN.LE.M) GO TO 14
   23 RETURN
      END
      SUBROUTINE MANYT(Z,T,ICOUNT,I       )
C
C     GENERAL INFORMATION AS TO THIS SUBROUTINE'S FUNCTION:
C
C           THIS IS THE GENERALIZED 24-9643R55 009 PR6F9-4 FOUR, FOR THE
C           LOCATION AND IDENTIFICATION OF DISTINCT MULTIPLE THERMOCLINES
C           ON A GIVEN BATHYMETRIC TRACE.  AS WRITTEN IT IS FLEXIBLE
C           ENOUGH TO IDENTIFY UP TO AND INCLUDING THREE SEPERATE AND
C           DISCTINCT THERMOCLINES.
C
C
C
C           THE INPUTS FROM THE MAIN PROGRAM ARE AS FOLLOWS:
C
C                 Z(I) - THE DEPTHS AS SELECTED AGAINST THE CHOSEN
C                        TEMPERATURE INTERVAL
C                 T(I) -  THE TEMPERATURES CORRESPONDING TO THE
C                         Z(I) ABOVE
C                 ICOUNT - THE NUMBER OF DATA PAIRS IN THIS TRACE
C
C
C     METHOD OF ANALYSIS:
       A1=1
C
C           THIS SUBROUTINE TAKES THE DATA INPUT FROM THE MAIN PROGRAM
C           AND ANALYZES THE SLOPES ALONG THIS TRACE LOOKING FOR A CHANGE
C           IN SIGN.   ONCE THE DIFFERENT ROUGH AREAS HAVE BEEN SO
C           DEFINED THE PROGRAM THEN MATHEMATICALLY WORKS OUT THE CENTER
C           OF EACH SUB-THERMOCLINE ON THE BATHYMETRIC TRACE AND ALSO
C           PICKS OUT THE SEPERATION POINT BETWEEN EACH SEPERATE SUB-
C           THERMOCLINE.  AFTER DEFINING THE REGION OF EACH SUB-THERMO.
C           THE PROGRAM THEN CALLS GAUSS3, A SUBROUTINE THAT USES A
C           STRAIGHT GAUSSIAN ANALYSIS TO DETERMINE THE GAUSSIAN TOP
C           AND BOTTOM OF THIS SUB-THERMOCLINE.
C
C
      A2=1
C
C     SPECIAL NOTES FOR THE USER:
C
C           NOTE THAT THE GAUSSIAN DEFINITION OF THE BOTTOM OF THE
C           THERMOCLINE DOES NOT CORRESPOND WITH THE SEPERATION  POINT
C           AS DEFINED.  NOTE ALSO, THAT THE BOTTOM OF ONE THERMOCLINE
C           DOES NOT MATCH THE TOP OF THE NEXT SUBSEQUENT THERMOCLINE.
C           THIS IS BECAUSE OF THE NATURE OF THE GAUSSIAN ANALYSIS,
C           IN THAT THERE IS A CHOSEN VALUE OF SIGMA (SK = STANDARD
C           DEVIATION) USED THAT DOES NOT ALLOW ACCURACY OVER THE  FULL
C           CURVE.  SEE THE OUTLINED METHODOLOGY IN THE WRITE UP OF THIS
```

```
C            THESIS BEFORE DECIDING WHICH VALUE TO USED BASED UPON USAGE
C            OF FINAL DATA OUTPUT.
C
C
C      OTHER SUBROUTINES CALLED FROM THIS SUBROUTINE:
C
C            GAUSS3(Z,T,ICOUNT) - TO OBTAIN TOP AND BOTTOM OF EACH
C                                 OF THE MULTIPLE THERMOCLINES
C
C            NONGA(Z,T,ICOUNT)  - IF NO MULTIPLE THERMOCLINES EXIST, THEN
C                                 WE ANALYZE THE THERMOCLINE BY NON-
C                                 GAUSSIAN METHODS.
C
C
C
C
C
C
      DIMENSION Z(50), Z6(50), Z8(50), NNO(20), T(50), T4(50), Z4(50)
      DIMENSION Z13(100)
      DIMENSION Z7(50), Z5(50), T7(50), T5(50)
      DIMENSION Z9(20), T9(20)
      JCOUNT = 0
      WRITE(6,5107)
 5107 FORMAT(//5X,' * * * THE FOLLOWING OUTPUT FIGURES REPRESENT THE RES
     *ULTS',   ' FOR MULTIPLE THERMOCLINES IN THIS BT TRACE * * * ',///)
   79 MM = ICOUNT
      DO 108 I11=1,ICOUNT
C     WRITE(6,107) Z(I11)
C 107 FORMAT(//3X, F10.6,//)
  108 CONTINUE
      LQ1 = I - ICOUNT
      LQ2 = I - 2
      LQ3 = I - 3
      LQ4 = LQ1 + 1
      LQ5 = LQ1 + 2
      M = I - 3
C     WRITE(6,6103) I,LQ1,LQ2,LQ3,LQ4,LQ5
C6103 FORMAT(//3X,'VARIABLES INPUT TO MANYT = ', 6I4,/)
      DO 40 N2=LQ1, LQ2
      Z6(N2) = Z(N2+1) - Z(N2)
   40 CONTINUE
      DO 41 N1=LQ1, LQ3
      Z8(N1) = Z6(N1+1) - Z6(N1)
   41 CONTINUE
      N = LQ1
      K = 0
      J=0
```

```
    2 IF(Z8(N).LT.0.0) GO TO 1                                          0861
      N = N +1                                                          0862
      IF(N.LE.M) GO TO 2                                                0863
      IF(N.GT.M) GO TO 5                                                0864
    1 NQQ = N + 1                                                       0865
      IF(Z8(NQQ).LT.0.0) N=N+1                                          0866
      IF(Z8(NQQ).LT.0.0) GO TO 2                                        0867
      IF(Z8(NQQ).GE.0.0) J=J+1                                          0868
      K = K +1                                                          0869
      JCOUNT = JCOUNT + 1                                               0870
      NQ = N +2                                                         0871
      NNQ(J) = N +2                                                     0872
      WRITE(6,4)  K, Z(NQ)                                              0873
    4 FORMAT(//10X,'CENTER NUMBER',I2,'   LOCATED AT . . . . . . . . . . '0874
     *  ,F5.1)                                                          0875
      N = N + 1                                                         0876
      IF(N.EQ.M) GO TO 5                                                0877
      IF(N.LT.M) GO TO 2                                                0878
    5 IF(JCOUNT.EQ.1) GO TO 1135                                        0879
      NQ1 = NNQ(LQ1)                                                    0880
      NQ2 = NNQ(LQ4) - 1                                                0881
      BIG1 = ABS(Z6(NQ1))                                               0882
      J = NQ1                                                           0883
      NQN1 = NQ1 + 1                                                    0884
C     WRITE(6,5000) NQ1, NQ2, NQN1, BIG1                                0885
C5000 FORMAT(//3X , 3I6, F10.3, /////)                                  0886
      DO 100 K1= NQN1, NQ2                                              0887
      IF(ABS(Z6(K1)).LT.BIG1) GO TO 100                                 0888
      BIG1 = ABS(Z6(K1))                                                0889
      BIGDP1 = 0.500000*( Z(K1) +  Z(K1+1))                             0890
C     WRITE(6,5001) BIG1, BIGDP1                                        0891
C5001 FORMAT(//3X, 2F10.3 //)                                           0892
      J = K1                                                            0893
  100 CONTINUE                                                          0894
      NNNN1=NQN1 + 1                                                    0895
      DO 5101 I50=1,NNNN1                                               0896
      Z4(I50) = Z(I50)                                                  0897
      T4(I50) = T(I50)                                                  0898
C     WRITE(6,6101) Z4(I50)                                             0899
C6101 FORMAT(//3X,'Z4(I50) = ', F10.3, /)                               0900
 5101 CONTINUE                                                          0901
C     WRITE(6,6102) NQN1                                                0902
C6102 FORMAT(//3X,'NQN1 = ' ,I3,//)                                     0903
      CALL GAUSS3(Z4,T4,ICOUNT,NQN1                         )           0904
      WRITE(6,104)  BIGDP1                                              0905
  104 FORMAT(//10X,'SEPERATION #1 BETWEEN THERMOCLINES . . . . . . . . . '0906
     * ,F5.1)                                                           0907
      IF(JCOUNT.LE.2) GO TO 115                                         0908
      NQ3 = NNQ(LQ4)
      NQ4 = NNQ(LQ5) - 1
      BIG2 = ABS(Z6(NQ3))
      J = NQ3
      NQN2 = NQ3 + 1
      DO 101 K2=NQN2, NQ4
      IF(ABS(Z6(K2)).LT.BIG2) GO TO 101
      BIG2 = ABS(Z6(K2))
      BIGDP2 = 0.50000*(Z(K2) + Z(K2+1))
      J = K2
  101 CONTINUE
C     WRITE(6,5103) NQ3,NQ4,NON2,J
C5103 FORMAT(//20X,4I6,//)
      NNNN2 = NQ4 - 1
      K22 = NNNN2 - NQN1
      K221 = K22 + 1
      I55=1
      DO 5201 I59=NQN1,NNNN2
      Z5(I55) = Z(I59)
      T5(I55) = T(I59)
      I55 = I55 + 1
 5201 CONTINUE
      CALL GAUSS3(Z5,T5,ICOUNT,K22      )
      WRITE(6,105)  BIGDP2
  105 FORMAT(//10X,'SEPERATION #2 BETWEEN THERMOCLINES . . . . . . . . '
     * ,F5.1)
      K23 = ICOUNT - J - 1
      K231 = K23 + 1
      I56 = 1
      DO 5301 I54=NNNN2,ICOUNT
      Z7(I56) = Z(I54)
      T7(I56) = T(I54)
      I56 = I56+1
 5301 CONTINUE
      CALL GAUSS3(Z7,T7,ICOUNT,K23      )
      IF(JCOUNT.GT.2) GO TO 113
  115 K25=ICOUNT-NQN1
      I60=1
      DO 5401 I61=NQN1,ICOUNT
      Z9(I60) = Z(I61)
      T9(I60) = T(I61)
      I60 = I60 + 1
 5401 CONTINUE
      CALL GAUSS3(Z9,T9,ICOUNT,K25      )
      IF(ICOUNT.GE.1) GO TO 113
 1135 CALL NONGA(Z,T,ICOUNT)
  113 WRITE(6,42)  ICOUNT
   42 FORMAT(//10X, ' * * * * * * * * * * END OF DATA FOR THIS BATHYTHER
     *MOGRAPH SLIDE * * * NUMBER OF DATA PAIRS ANALYZED = ',I2,//)
      RETURN
      END


      SUBROUTINE SEE13(T,Z,ICOUNT)
C
C
C
C
      DIMENSION T(30), Z(30),Z13(50)
      DO 13 I=1,ICOUNT
      Z13(I) = -Z(I)
C     WRITE(6,14) Z13(I)
C  14 FORMAT(//3X, F10.3,//)
   13 CONTINUE
      RETURN
      END


      SUBROUTINE GAUSS3(Z,T,ICOUNT,NON1     )
C
C
C
C     GENERAL INFORMATION CONCERNING GAUSSIAN SUBROUTINE:
C
C           THIS SEGMENT, ENTITLED "GAUSS3", USES A GAUSSIAN METHOD TO
C           ANALYZE FOR THE TOP, CENTER, AND BASE OF EACH THERMOCLINE
C           WHEN CALLED FROM "MANYT".
C
C     INPUTS FROM "MANYT":
C
C           Z(I)   - DEPTHS FROM SURFACE DOWN.
C
C           NT     - INTERNAL COUNTER FOR USE IN DO-LOOP CONTROL.
C
C           ICOUNT - NUMBER OF DATA PAIRS UTILIZED IN COMPUTATION.
C
C
C
C
      DIMENSION T(50),Z(50), Z1(50),Z2(50),ZA(50),ZB(50)
      EQUIVALENCE(ZA(1),Z1(1)), (ZB(1),Z2(1))
      IF((T(1)-T(2)).GE.1.0) SK=1.30000
      IF((T(1)-T(2)).LE.0.5) SK= 1.470000
      K21=NON1
      K212 = NON1 + 1
      DO 4302 I=1,K212
C     WRITE(6,34) Z(I)
C  34 FORMAT(//3X,'Z(GAUSS) = ' ,F10.3,/)
 4302 CONTINUE
      CALL ORDER3(Z,T,K21)
      DO 4300 N=1,K21
      Z1(N)=(Z(N) + Z(N+1))/2.0
      Z2(N)=(Z1(N))**2.0
 4300 CONTINUE
      SUM1=0.0
      SUM2=0.0
      DO 4301 N1=1,K21
      SUM1= SUM1 + ZA(N1)
      SUM2= SUM2 + ZB(N1)
 4301 CONTINUE
      IR =NON1 +1
      WRITE(6,30) IR
   30 FORMAT(//10X 'NUMBER OF DATA PAIRS UTILIZED = ' I6)
      ZC =(1.0/(IR -1))*SUM1
      WRITE(6,31) ZC
   31 FORMAT(//10X 'CENTER OF GAUSSIAN THERMOCLINE IS LOCATED AT DEPTH
     * = ' F10.6)
      ZAVG = (1.0/(IR-1))*SUM2
      SIGMA = SQRT(ZAVG - (ZC*ZC))
      ZT  = ZC -SK*SIGMA
      WRITE (6,32) ZT
   32 FORMAT(//10X ' TOP OF GAUSSIAN THERMOCLINE IS LOCATED AT DEPTH = '
     *F10.6)
      ZBT = ZC +SK*SIGMA
      WRITE (6,33) ZBT
   33 FORMAT(//10X ' BOTTOM OF GAUSSIAN THERMOCLINE IS LOCATED AT DEPTH
     * = ' F10.6)
      WW = ZBT - ZT
      RETURN
      END
      SUBROUTINE ORDER3(X,Y,K21)
C
C
C
C
C
C
C
C
C
C THIS PROGRAM IS DESIGNED TO ARRANGE A DISORDED ARRAY IN DESCENDING ORDER
C HERE WE WILL USE THE GAUSS DATA AND CONCENTRATE ON THE X,OR DEPTH VALUE
C VICE THE Y WHICH ARE THE TEMPERATURE VALUES ALTHOUGH THE CORRESPONDING
C TEMPERATURE VALUES WILL BE PRINTED WITH THE DEPTH
C
C
C
      DIMENSION X(12), Y(12)
      IMI=K21 - 1
      DO 12 I=1,IMI
      IP1 = I +1
      DO 12 J=IP1,IMI
      IF(X(I).LE.X(J)) GO TO 12
      TEMP = X(I)
      X(I) = X(J)
      X(J) = TEMP
      TEMP = Y(I)
      Y(I) = Y(J)
      Y(J) = TEMP
   12 CONTINUE
C     WRITE(6,35)
C  35 FORMAT(//10X 'ORDERED DATA PAIRS FROM THE SURFACE' // T18, 'DEPTH'
C    *T30, 'TEMPERATURE' //)
C     WRITE(6,36) (X(I),Y(I),I=1,K21)
C  36 FORMAT(T10, 2F15.7, //)
      RETURN
      END
      SUBROUTINE NONGA(Z,T,ICOUNT)
C
C
C     GENERAL INFORMATION CONCERNING THE NON-GAUSSIAN SUBROUTINE:
C
C           THIS SEGMENT, ENTITLED "NONGA", WHEN CALLED BY "MANYT", WILL
C           USE NON-GAUSSIAN FINITE DIFFERENCE METHODS TO ANALYZE FOR
C           THE SIGNFICANT FEATURES (IF ONLY A SINGLE THERMOCLINE
C           EXISTS).
C
C
C     METHOD OF ANLAYSIS:
C
C           THIS SEGMENT USES FIRST AND SECOND DIFFERENCES TO FIND
C           APPLICABLE PORTIONS OF THE SLOPE, WHICH ONCE DEFINED ARE
C           USED IN A GAUSSIAN SCHEME TO FIND THE TOP, CENTER, AND BASE
C           OF THIS SINGLE THERMOCLINE.
C
C
C     SUBROUTINES CALLED FROM "NONGA":
C
C           GAUSS1 - FINDS CENTER AND TOP OF THERMOCLINE
C
C           GAUSS2 - FINDS BASE OF THERMOCLINE.
C
C           ORDER4 - ASSURES CORRECT ORDER FOR ANALYSIS.
C
C
C
C
      DIMENSION Z(25), Z1(25), Z2(25), TEST(25), Z3(25), Z4(50), Z5(50)
      DIMENSION T(50)
      IF((T(1)-T(2)).GE.1.0) SK=1.30000
      IF((T(1)-T(2)).LE.0.5) SK= 1.470000
      III = ICOUNT
      CALL ORDER4(Z,III)
      M = III - 1
      MM = M -1
      N = 1
    1 Z1(N) = Z(N+1) - Z(N)
C     WRITE(6,2001)
C2001 FORMAT(//3X 'Z1(N)' //)
C     WRITE (6,2002) Z1(N)
C2002 FORMAT(/3X, F10.6, /)
      N = N + 1
      IF(N.LE.M) GO TO 1
      J = 1
    2 Z2(J) = Z1(J+1) - Z1(J)
```

```
C     WRITF(6,46)
C  46 FORMAT(//3X'Z2(J)' //)
C     WRITE(6,2003) Z2(J)
C2003 FORMAT(/3X, F10.6 ,/)
      J = J + 1
      IF(J.LE.MM) GO TO 2
      KCOUNT = 0
      DO 3 KK= 1,10
      TEST(KK) = Z2(KK)
      KCOUNT = KCOUNT + 1
C     WRITE(6,47)
C  47 FORMAT(//3X ' TEST AND KCOUNT' //)
C     WRITE(6,2004) TEST(KK), KCOUNT
C2004 FORMAT(/3X, F10.6, I3, /)
      IF(TEST(KK).GT.0.0) GO TO 4
    3 CONTINUE
    4 KKK = KCOUNT
      NUMBER = III - KKK
      KDUMMY = NUMBER - 1
C     WRITE(6,2005) NUMBER
C2005 FORMAT(/3X, I5,/)
      NNN = KDUMMY  + NUMBER
C     WRITE(6,2006) NNN
C2006 FORMAT(/3X, I5,/)
      KN = KKK+1
      ZC = Z(KN)
      QQ = 2.0 * ZC
      DO 73 I1=1,KN
      Z5(I1) = Z(I1)
   73 CONTINUE
      DO 7 I2=1,25
      X = Z(KN) - Z(KN-I2)
C     WRITE(6,48)
C  48 FORMAT(//3X 'X' //)
C     WRITE(6,2007) X
C2007 FORMAT(/3X, F10.6,/)
      Z5(KN+I2) = Z(KN) + X
C     WRITE(6,49)
C  49 FORMAT(//3X 'Z5(KN+I)' //)
C     WRITE(6,2008) Z5(KN+I2)
C2008 FORMAT(/3X, F10.6,/)
C     IF(Z5(KN+I2).EQ.QQ) GO TO 5
    7 CONTINUE
    5 CALL GAUSS1(Z5, NUMBER, ICOUNT,SK)
      DO 74 I3=1,NUMBER
      Z3(KDUMMY + I3) = Z(KKK+I3)
   74 CONTINUE
      DO 59 I4=1,KDUMMY
      X = Z(KN+I4) - Z(KN)
C     WRITE(6,68)
C  68 FORMAT(//3X 'X' //)
C     WRITE(6,2009)    X
C2009 FORMAT(/3X, F10.6,/)
      Z3(NUMBER - I4) = Z(KN) - X
C     WRITE(6,69)
C  69 FORMAT(//3X 'Z3(NUMBER - I)' //)
C     WRITE(6,2010) Z3(NUMBER-I4)
C2010 FORMAT(/3X, F10.6,/)
   59 CONTINUE
C     WRITE(6,77)
C  77 FORMAT(//3X 'Z3(J)' //)
C     WRITE(6,100)  (Z3(J1), J1=1,NNN)
C 100 FORMAT(T5, F15.7, //)
      CALL GAUSS2(Z3,NNN,ICOUNT,SK)
      RETURN
      END


      SUBROUTINE GAUSS1( X, NT, ICOUNT, SK)
C
C
C     GENERAL INFORMATION CONCERNING GAUSSIAN SUBROUTINE:
C
C           THIS SEGMENT, ENTITLED "GAUSS1", USES A GAUSSIAN METHOD TO
C           FIND THE CENTER AND THE TOP OF EACH THERMOCLINE IN "MANYT".
C
C
C     INPUTS FROM "MANYT":
C
C           Z(I)    - DEPTHS FROM SURFACE DOWN.
C
C           T(I)    - TEMPERATURES FROM SURFACE DWON.
C
C           ICOUNT  - NUMBER OF DATA PAIRS UTILIZED IN COMPUTATION.
C
C           NONJ    - INTERNAL COUNTER USED IN DO-LOOP CONTROL.
C
C
C
C
      DIMENSION X(12), Y(12),Z1(12), Z2(12), ZA(12),ZB(12)
      EQUIVALENCE(ZA(1),Z1(1)), (ZB(1),Z2(1))
      N = 1
      M = NT - 1
```

```
    1 Z1(N) =(X(N) + X(N+1))/2.0
C     WRITE(6,2011) Z1(N)
C2011 FORMAT(/3X, F10.3,/)
      Z2(N) = (Z1(N))*(Z1(N))
C     WRITE(6,2012) Z2(N)
C2012 FORMAT(/3X, F10.3,/)
      N = N +1
      IF(N.LE.M) GO TO 1
      SUM1 =0.0
      J = 1
  180 SUM1 = SUM1 + ZA(J)
      J = J + 1
      IF(J.LE.M) GO TO 180
C     WRITE(6,2013) SUM1
C2013 FORMAT(/3X, F10.3,/)
      SUM2 = 0.0
      K = 1
  181 SUM2 = SUM2 +ZB(K)
      K = K + 1
      IF(K.LE.M) GO TO 181
C     WRITE(6,2023) SUM2
C2023 FORMAT(/3X, F10.3,/)
      IR=NT-1
      ZC = (1.0/(IR))* SUM1
      ZAVG = (1.0/(IR))*SUM2
C     WRITE(6,2014) ZAVG
C2014 FORMAT(/3X, F10.3,/)
      SIGSQR = ZAVG - (ZC*ZC)
C     WRITE(6,2015) SIGSQR
C2015 FORMAT(/3X, F10.3,/)
      ZT  = ZC -SK * SQRT(SIGSQR)
      CALL PRINT1(ZC,ZT,ICOUNT)
      RETURN
      END


      SUBROUTINE GAUSS2( X, NT, ICOUNT, SK)
C
C
C     GENERAL INFORMATION CONCERNING GAUSSIAN SUBROUTINE:
C
C           THIS SEGMENT, ENTITLED "GAUSS2", USES A GAUSSIAN METHOD TO
C
C           ANALYZE FOR THE BASE OF EACH THERMOCLINE WHEN CALLED FROM
C           "MANY".
C
```

```
C
C     INPUTS FROM "MANYT":
C
C           Z(I)    - DEPTHS FROM SURFACE DOWN.
C
C           NT      - INTERNAL COUNTER FOR USE IN DO-LOOP CONTROL.
C
C           ICOUNT - NUMBER OF DATA PAIRS UTILIZED IN COMPUTATION.
C
C
C
C
C
      DIMENSION X(12), Y(12),Z1(12), Z2(12), ZA(12),ZB(12)
      EQUIVALENCE(ZA(1),Z1(1)), (ZB(1),Z2(1))
      N = 1
      M = NT - 1
    1 Z1(N) =(X(N) + X(N+1))/2.0
C     WRITE(6,2016) Z1(N)
C2016 FORMAT(/3X, F10.3,/)
      Z2(N) = (Z1(N))*(Z1(N))
C     WRITE(6,2017) Z2(N)
C2017 FORMAT(/3X, F10.3,/)
      N = N +1
      IF(N.LE.M) GO TO 1
      SUM1 =0.0
      J = 1
  180 SUM1 = SUM1 + ZA(J)
      J = J + 1
      IF(J.LE.M) GO TO 180
C     WRITE(6,2018) SUM1
C2018 FORMAT(/3X, F10.3,/)
      SUM2 = 0.0
      K = 1
  181 SUM2 = SUM2 +ZB(K)
      K = K + 1
      IF(K.LE.M) GO TO 181
C     WRITE(6,2019) SUM2
C2019 FORMAT(/3X, F10.3,/)
      IR=NT-1
      ZC = (1.0/(IR))*SUM1
      ZAVG = (1.0/(IR))*SUM2
C     WRITE(6,2020) ZAVG
C2020 FORMAT(/3X, F10.3,/)
      SIGSQR = ZAVG - (ZC*ZC)
C     WRITE(6,2021) SIGSQR
C2021 FORMAT(/3X, F10.3,/)
      ZBT = ZC +SK * SQRT(SIGSQR)
      CALL PRINT2(ZBT)
      RETURN
      END


      SUBROUTINE PRINT1(ZC,ZT,ICOUNT)
C
C
C
C
C
C
C
      WRITE(6,1000) ICOUNT
 1000 FORMAT(//18X,'NUMBER OF DATA PAIRS UTILIZED FOR TOP AND CENTER . '
     * ,F5.1)
      WRITE (6,32) ZT
      WRITE(6,31) ZC
   31 FORMAT(//18X,'TOP OF THERMOCLINE LOCATED AT DEPTH  . . . . . . . . '
     * ,F5.1)
   32 FORMAT(//18X,'CENTER OF THERMOCLINE LOCATED AT DEPTH . . . . . . . '
     * ,F5.1)
      RETURN
      END


      SUBROUTINE PRINT2(ZBT)
C
C
C     GENERAL INFORMATION CONCERNING PRINTING SUBROUTINE:
C
C           THIS SEGMENT, ENTITLED "PRINT2", WHEN CALLED FROM "GAUSS2"
C           WILL PRINT OUT THE BASE OF THE THERMOCLINE.
C
C
C     INPUTS FROM "GAUSS2":
C
C           ZBT  - DEPTH OF BASE OF THERMOCLINE.
C
C
C
C
      WRITE(6,33) ZBT
   33 FORMAT(//18X,'BASE OF THERMOCLINE LOCATED AT DEPTH . . . . . . . . '
     * ,F5.1)
       RETURN
       END


       SUBROUTINE ORDER4( X, KT)
C
C
C      GENERAL INFORMATION CONCERNED WITH ORDERING SUBROUTINE:
C
C            THIS SEGMENT, ENTITLED "ORDER4C, WHEN CALLED FROM "NONGA"
C            WILL INUSRE, BY NUMERICAL METHODS, THAT THE DATA IS IN
C            CORRECT ORDER FROM THE SURFACE DOWN.
C
C
C      INPUTS FROM "NONGA":
C
C            Z(I)   - DEPTHS FROM INPUT SOURCE.
C
C            KT     - INTERNAL COUNTER TO CONTROL DO-LOOPS.
C
C
C
       DIMENSION X(25)
       KTK = KT - 1
       DO 12 I =1,KTK
       IP1 = I + 1
       DO 12 J=IP1,KTK
       IF(X(I).LE.X(J)) GO TO 12
       TEMP = X(I)
       X(I) = X(J)
       X(J) = TEMP
    12 CONTINUE
C      WRITE(6,35)
C   35 FORMAT(//10X 'ORDERED DEPTHS FROM SURFACE' // T18, 'DEPTH' //)
C      WRITE(6,36)          (X(I5), I5=1,KT)
C   36 FORMAT(T10, F15.7, //)
       RETURN
       END
```

```
      SUBROUTINE PRINT7(LAT, LONG,YLONG,QUAD1,QUAD2, DATE1, DATE2,DATE3,
     *TIME, XLAT,SERIAL)
C
C
C
C
C
C
C
C
C
C
C
C        QUAD1 CORRESPONDS TO NORTH-SOUTH
C
C        QUAD2 CORRESPONDS TO EAST-WEST
C
      INTEGER QUAD1, QUAD2, DATE1, DATE2, DATE3, TIME,SERIAL
      IF(QUAD1.EQ.1) GO TO 1
      IF(QUAD1.EQ.2) GO TO 2
    1 IF(QUAD2.EQ.1) GO TO 3
      IF(QUAD2.EQ.2) GO TO 4
    2 IF(QUAD2.EQ.1) GO TO 5
      IF(QUAD2.EQ.2) GO TO 6
    3 WRITE(6,7) LAT,XLAT,LONG,YLONG,DATE1,DATE2,DATE3,TIME,SERIAL
    7 FORMAT(//10X,'GEOGRAPHIC POSITION OF BATHYMETRIC TRACE:',//,18X,
     *'LATITUDE . . . . . . . . . . . . . . . . . .',T64,I2,' - ',F5.2,' NORTH',
     */,18X,'LONGITUDE. . . . . . . . . . . . . . . . .',T63,I3,' - ',F5.2,
     *' EAST',///,10X,'DATE AND TIME OF BATHYMETRIC TRACE',//,18X,'DATE
     *. . . . . . . . . . . . . . . . . . . .',T66,I2,'/',I2,'/',I2,/,18X,'TIME
     *. . . . . . . . . . . . . . . . . . . .',T67,I7,' GMT'///,10X,'BATHYTHERMO
     *GRAPH SERIAL NUMBER',//,18X,'BT SERIAL NO. . . . . . . . . . . . .'
     *,T72,I8,////)
      IF(QUAD1.EQ.1.AND.QUAD2.EQ.1) GO TO 11
    4 WRITE(6,8) LAT,XLAT,LONG,YLONG,DATE1,DATE2,DATE3,TIME,SERIAL
    8 FORMAT(//10X,'GEOGRAPHIC POSITION OF BATHYMETRIC TRACE:',//,18X,
     *'LATITUDE . . . . . . . . . . . . . . . . . .',T64,I2,' - ',F5.2,' NORTH',
     */,18X,'LONGITUDE. . . . . . . . . . . . . . . . .',T63,I3,' - ',F5.2,
     *' WEST',///,10X,'DATE AND TIME OF BATHYMETRIC TRACE:',//,18X,'DATE
     *. . . . . . . . . . . . . . . . . . . .',T66,I2,'/',I2,'/',I2,/,18X,'TIME
     *. . . . . . . . . . . . . . . . . . . .',T67,I7,' GMT'///,10X,'BATHYTHERMO
     *GRAPH SERIAL NUMBER',//,18X,'BT SERIAL NO. . . . . . . . . . . . .'
     *,T72,I8,////)
      IF(QUAD1.EQ.1.AND.QUAD2.EQ.2) GO TO 11
    5 WRITE(6,9) LAT,XLAT,LONG,YLONG,DATE1,DATE2,DATE3,TIME,SERIAL
    9 FORMAT(//10X,'GEOGRAPHIC POSITION OF BATHYMETRIC TRACE:',//,18X,
     *'LATITUDE . . . . . . . . . . . . . . . . . .',T64,I2,' - ',F5.2,' SOUTH',
     */,18X,'LONGITUDE. . . . . . . . . . . . . . . . .',T63,I3,' - ',F5.2,
     *' EAST',///,10X,'DATE AND TIME OF BATHYMETRIC TRACE:',//,18X,'DATE
C                                                                               0002
     *. . . . . . . . . . . . . . . .',T66,I2,'/',I2,'/',I2,/,18X,'TIME         1438
     *. . . . . . . . . . . . . . . .',T67,I7,' GMT'///,10X,'BATHYTHERMO        1439
     *GRAPH SERIAL NUMBER',//,18X,'BT SERIAL NO.  . . . . . . . . . . .'        1440
     *,T72,I8,////)                                                             1441
      IF(QUAD1.EQ.2.AND.QUAD2.EQ.1) GO TO 11                                    1442
    6 WRITE(6,10)LAT,XLAT,LONG,YLONG,DATE1,DATE2,DATE3,TIME,SERIAL              1443
   10 FORMAT(//10X,'GEOGRAPHIC POSITION OF BATHYMETRIC TRACE:',//,18X,          1444
     *'LATITUDE . . . . . . . . . . .',T64,I2,' - ',F5.2,' SOUTH',              1445
     */,18X,'LONGITUDE. . . . . . . .',T63,I3,' - ',F5.2,                       1446
     *' WEST',///,1CX,'DATE AND TIME OF BATHYMETRIC TRACE:',//,18X,'DATE        1447
     *. . . . . . . . . . . . . . . .',T66,I2,'/',I2,'/',I2,/,18X,'TIME         1448
     *. . . . . . . . . . . . . . . .',T67,I7,' GMT'///,10X,'BATHYTHERMO        1449
     *GRAPH SERIAL NUMBER',//,18X,'BT SERIAL NO.  . . . . . . . . . . .'        1450
     *,T72,I8,////)                                                             1451
      IF(QUAD1.EQ.2.AND.QUAD2.EQ.2) GO TO 11                                    1452
   11 RETURN                                                                    1453
      END                                                                       1454
C                                                                               0000
C                                                                               0000
C                                                                               0000
C                                                                               0000
C                                                                               0000
C                                                                               0000
C                                                                               0000
C                                                                               0000
C                                                                               0000
C                                                                               0000
C                                                                               0000
C                                                                               0000
C                                                                               0000
C                                                                               0000
C                                                                               0000
C                                                                               0000
C                                                                               0000
//GO.FT06F001 DD SPACE=(CYL,(15,2))                                             1455
//GO.SYSIN DD *                                                                 1457
```

APPENDIX III

WRITE-UP OF "DRAW" SUBROUTINE

```
C   SUBROUTINE DRAW(NUMPTS,X,Y,MODCURV,ITYPE,LABEL,ITITLE,EXSCALE,YSCALE,
C                  IXUP,IYRIGHT,MODEAX,MODEYAX,IWIDE,IHIGH,IGRID,LAST)
C
C
C   A GENERAL CURVE DRAWING AND POINT PLOTTING SUBROUTINE
C
C        PROGRAMMER     J.R. WARD
C        DATE           FEB. 1964, REVISED JUNE 1965
C        SYSTEM         FORTRAN 60
C        OUTPUT         LOGICAL TAPE NUMBER 8
C        NOTE           ASTERISKS MARK CHANGES FOR FORTRAN 63
C
C
C   INPUT ARGUMENTS ---
C
C        1. NUMPTS      NUMBER OF POINTS TO BE PLOTTED.  THIS MUST ALWAYS BE
C                       AT LEAST 2. AND MUST NOT EXCEED 30 FOR PLOTTING, OR
C                       900 FOR CURVE DRAWING.
C
C        2. X           ARRAY OF X-ORDINATES.  DIMENSION AT LEAST EQUAL TO
C                       NUMPTS AND NOT MORE THAN 900 IN CALLING PROGRAM.
C
C        3. Y           ARRAY OF Y-ORDINATES.  DIMENSION AS FOR X-ARRAY IN
C                       THE CALLING PROGRAM.
C
C        4. MODCURV     CONTROLS THE NUMBER OF CURVES, AND/OR SETS OF POINTS
C                       ON EACH GRAPH.  THE CODES ARE:
C
C                            0  ONLY ONE PLOT ON THIS GRAPH
C                            1  FIRST PLOT OF MULTI-PLOT GRAPH
C                            2  INTERMEDIATE PLOT ON MULTI-PLOT GRAPH
C                            3  LAST PLOT ON MULTI-PLOT GRAPH.
C
C        5. ITYPE       CONTROLS THE TYPE OF PLOT.  THE CODES ARE:
C
C                            0  STRAIGHT LINES JOIN SUCCESSIVE POINTS (STANDARD
C                               CURVE DRAWING)
C                            1  POINTS PLOTTED WITH A CROSS (X)
C                            2  POINTS PLOTTED WITH A PLUS (+)
C                            3  POINTS PLOTTED WITH A SQUARE
C                            4  POINTS PLOTTED WITH A DIAMOND
C                            5  POINTS PLOTTED WITH A TRIANGLE
C                       WHEN POINTS ARE BEING PLOTTED (ITYPE - 1 THRU. 5)
C                       THE POINTS ARE NOT CONNECTED.
C
C        6. LABEL       IF A CURVE IS BEING DRAWN (ITYPE=0), LABEL IS A FOUR
C                       CHARACTER BCD CURVE IDENTIFIER WHICH WILL BE REPRODUCED
C                       AT THE END OF THE CURVE.  FOR EXAMPLE, LABEL EQUALS
```

```
C                    4H ONE.  IF POINTS ARE BEING PLOTTED, LABEL IS AN 8-
C                    CHARACTER IDENTIFIER.  THE FIRST FOUR CHARACTERS ARE
C                    REPRODUCED WITH THE FIRST PLOTTED POINT, AND THE LAST
C                    FOUR WITH THE LAST POINT.  SET TO BLANK ANY UNWANTED
C                    CHARACTERS.
C
C      7. ITITLE     AN ARRAY OF TWELVE 8-CHARACTER BCD WORDS. THE FIRST
C                    SIX WORDS WILL BE REPRODUCED AS THE FIRST LINE OF THE
C                    GRAPH TITLE , AND THE LAST SIX WORDS WILL FORM THE
C                    SECOND LINE.  THE TITLE MUST INCLUDE THE USERS JOB
C                    IDENTIFICATION.  DIMENSION 12 IN CALLING PROGRAM, AND
C                    SET TO BLANK ALL UNWANTED CHARCTERS.
C
C      8. EXSCALE    X-SCALE (UNITS/INCH) AS POSITIVE FLOATING POINT
C                    VARIABLE WITH ONE FIGURE SIGNIFICANT.  SET TO ZERO
C                    FOR AUTO SCALE.
C
C      9. YSCALE     Y-SCALE (UNITS/INCH) AS POSITIVE FLOATING POINT
C                    VARIABLE WITH ONE FIGURE SIGNIFICANT. SET TO ZERO
C                    FOR AUTO SCALE.
C
C     10. IXUP       X-AXIS OFFSET FROM BOTTOM OF GRAPH IN INCHES.  THIS
C                    M ST NOT EXCEED IHIGH, AND MUST NOT BE NEGATIVE.
C
C     11.IYRIGHT     Y-AXIS OFFSET FROM LEFT MARGIN OF GRAPH IN INCHES
C                    AND MUST NOT EXCEED IWIDE, AND MUST NOT BE NEGATIVE.
C
C     12. MODEAX     MODE OF X-AXIS OFFSET.  SEE CODES BELOW:
C
C                        0  COMPUTED OFFSET, HOLDING ORIGIN ON GRAPH. THE
C                    CORRESPONDING IXUP OR IYRIGHT IS IGNORED.
C                        1  COMPUTED OFFSET, WITH ORIGIN OFF THE GRAPH, IF
C                           APPROPRIATE.  THE CORRESPONDING IXUP OR IYRIGHT
C                           IS IGNORED.  USE ONLY WITH AUTO SCALE.
C                        2  AXIS OFFSET AS SPECIFIED BY IXUP OR IYRIGHT.
C
C     13. MODEYAX    DETERMINES THE MODE OF Y-AXIS IN THE SAME WAY AS
C                    MODEAX, ABOVE, GOVERNS THE X-AXIS LOCATION.
C
C     14. IWIDE      WIDTH OF GRAPH IN INCHES.  THIS WIDTH MUST NOT EXCEED.
C                    ZERO WILL BE READ AS EIGHT INCHES.
C
C     15. IHIGH      HEIGHT OF GRAPH IN INCHES.  THIS MUST NOT EXCEED
C                    FIFTEEN.  ZERO WILL BE READ AS EIGHT INCHES.
C
C     16. IGRID      IF SET TO 1, A ONE INCH BY ONE INCH GRID WILL BE
C                    SUPERIMPOSED ON THE GRAPH.
C
```

```
C
C     17. LAST      INDICATES TO CALLING PROGRAM WHETHER LAST PLOT WAS
C                   COMPLETED SUCCESSFULLY.  THE CODES ARE:
C
C                        0  LAST PLOT COMPLETED SUCCESSFULLY
C                        1  LAST PLOT WAS NOT SUCCESSFULL
C                        2  LAST PLOT WAS NOT SUCCESSFULL AND NO FURTHER
C                           GRAPH OUTPUT WILL BE ATTEMPTED UNTIL MODCURV
C                           IS NEXT ONE OR ZERO.
C                        3  DRAW WAS ENTERED WITH MODCURV NOT EQUAL TO ONE
C                           OR ZERO WHILE THE ERROR LOCKOUT WAS SET.
C                  THIS ARGUMENT MUST ALWAYS BE A NAME IN THE CALL
C                   STATEMENT.  NEVER A NUMBER.
C
C
C      NOTE ---
C
C         ALL ARGUMENTS FROM NUMBER 7 THRU. MUMBER 16 ARE IGNORED WHEN
C         MODCURV IS EITHER 2 OR 3.  HOWEVER, ARGUMENTS MUST NEVER BE
C         OMITTED FROM CALLING STATEMENT.  IT IS MERELY THEIR VALUES WHICH
C         ARE IRRELEVANT.  ARGUMENTS MAY BE LISTED BY NAME OR VALUE IN THE
C         CALL STATEMENT.  NO VALUE IN THE CALLING PROGRAM WILL BE
C         ALTERED BY THIS SUBROUTINE.
C
C
C      REFERENCE ---
C
C
C         THE BINARY TAPE FORMAT REQUIRED BY THE OFF-LINE PLOTTER IS
C         DESCRIBED IN THE WRITE-UP OF THE CDC 1604 GRAPH PLOT PROGRAM,
C         (IDENT.BC01).  THE FORMAT REQUIRED BY THE CDC 1604 PROGRAM IS
C         SIMILAR EXCEPT THAT THE INTERPOLATION ARGUMENT MUST BE ZERO.
C
C
C
```

APPENDIX IV

"BCD" CONVERSION PROGRAM

```
      DIMENSION INPUT(20)
 1    READ(5,1001, END=2)
 1001 FORMAT(20A4)
      CALL TRANS(INPUT)
      WRITE(6,2001) INPUT
 2001 FORMAT(1X, 20A4)
      WRITE(7,1001) INPUT
      GO TO 1
 2    STOP
      END
C
C
C
C
C
C     EXTERNAL SYMBOL DICTIONARY
C
C     SYMBOL    TYPE  ID  ADDR  LENGTH  LD  ID
C
C     TRANS      SD    01 000000 000180
C
C
      LOC   OBJECT CODE      ADDR1  ADDR2    STMT   SOURCE   STATEMENT
                                                1            MACRO
                                                2   &NAME    RETG
                                                3   &NAME    L     13,4(13)
                                                4            RETURN (14,12),T,RC,0
                                                5            MEND
                                                6            MACRO
                                                7   &NAME    STARTG
                                                8   &NAME    CSET
                                                9            USING  *,15
                                               10            SAVE  (14,12),T,*
                                               11            LR    12,13
                                               12            CNOP    0,4
                                               13            BAL    13,*  +76
                                               14            DROP    15
                                               15            USING  *,13
                                               16            DS     18F
                                               17            ST      13,8(12)
                                               18            ST      12,4(13)
                                               19            MEND
                                               20   TRANS    STARTG
      000000                                   21+  TRANS    CSECT
      000000                                   22+  TRANS    USING *, 15
      000004 47F0 F001              0000A      23+           B     10(0,15)
                                                             BRANCH AROUND ID
      000004 05                                24+           DC    AL1(5)
```

```
000005 E3D9C1D5F2                    25+          DC    CL5'TRANS'
                                                  IDENTIFIER
00000A 90EC D00C            0000C    26+          STM   14,12,12(13)
                                                  SAVE REGISTERS
00000E 18CD                          27+          LR    12,13
000010                               28+          CNOP  0,4
000010 45D0 ;05C            0005C    29+          BAL   13, * +76
                                     30+          DROP  15
000014                               31+          USING *,13
000014                               32+          DS    18F
00005C 50DC 0008            00008    33+          ST    13,8(12)
000060 50CD 0004            00004    34+          ST   12,4(13)
000064 5831 0000            00000    35           L     3,0(1,0)
000068 DC4F 3000 D06C 00000 00080    36           TR    0(80,3) TABLE
                                     37           RETG
00006E 58DD 0004            00004    38+          L     13,4(13)
000072 98EC D00C            0000C    39+          LM     14,12,12(13)
                                                  RESTORE THE REGISTERS
000076 92FF D00C      0000C          40+          MVI 12(13),X,'FF'
                                                  SET RETURN INDICATION
00007A 41F0 0000            00000    41+          LA  15,0(0,0)
                                                  LOAD RETURN CODE
00007E 07FE                          42+          RETURN
000080 4040404040                    43   TABLE   DC CL5'       '
000085 4040404040                    44           DC CL5'       '
00008A 4040404040                    45           DC CL5'       '
00008F 4040404040                    46           DC CL5'       '
000094 4040404040                    47           DC CL5'       '
000099 4040404040                    48           DC CL5'       '
00009E 4040404040                    49           DC CL5'       '
0000A3 4040404040                    50           DC CL5'       '
0000A8 4040404040                    51           DC CL5'       '
0000AD 4040404040                    52           DC CL5'       '
0000B2 4040404040                    53           DC CL5'       '
0000B7 4040404040                    54           DC CL5'       '
0000BC 40404040                      55           DC CL4'      '
0000C0 4040404040                    56           DC CL5'       '
0000C5 4040404040                    57           DC CL5'       '
0000CA 404B406C50                    58           DC CL5' . %&& '
0000CF 4050404040                    59           DC CL5' &&    '
0000DA 4040404040                    60           DC CL5'       '
0000D9 40405B5C4C                    61           DC CL5'  $*<  '
0000DE 5E40606140                    62           DC CL5'; -/   '
0000E3 4040404040                    63           DC CL5'       '
0000E8 4040406B40                    64           DC CL5'       '
0000ED 404EC04040                    65           DC CL5'404EC040'
0000F2 4040404040                    66           DC CL5'       '
0000F7 4040407D7B                    67           DC CL5'   ''# '
```

```
0000FC 7C407B40                  68          DC CL4'@ #   '
000100 4040404040                69          DC CL5'     '
000105 4040404040                70          DC CL5'     '
00010A 4040404040                71          DC CL5'     '
00010F 4040404040                72          DC CL5'     '
000114 4040404040                73          DC CL5'     '
000119 4040404040                74          DC CL5'     '
00011E 4040404040                75          DC CL5'     '
000123 4040404040                76          DC CL5'     '
000128 4040404040                77          DC CL5'     '
00012D 4040404040                78          DC CL5'     '
000132 4040404040                79          DC CL5'     '
000137 4040404040                80          DC CL5'     '
00013C 40404040                  81          DC CL4'    '
000140 40C1C2C3C4                82          DC CL5' ABCD'
000145 C5C6C7C8C9                83          DC CL5'EFGHI'
00014A 4040404040                84          DC CL5'     '
00014F 4040D1D2D3                85          DC CL5'  JKL'
000154 D4D5D6D7D8                86          DC CL5'MNOPQ'
000159 D940404040                87          DC CL5'R    '
00015E 40404040E2                88          DC CL5'    S'
000163 E3E4E5E6E7                89          DC CL5'TUVWX'
000168 E8E9404040                90          DC CL5'YZ   '
00016D 404040F0F1                91          DC CL5'   01'
000172 F2F3F4F5F6                92          DC CL5'23456'
000177 F7F8F94040                93          DC CL5'789  '
00017C 40404040                  94          DC CL4'    '
                                 95          END
C
C
C
C
C     NOTE ---
C
C
C     THE PRECEDING PROGRAM IS THE MAIN PROGRAM TO CONVERT A
C     WRITTEN PROGRAM (PUNCHED) FROM THE IBM 360 SERIES FORMAT TO THE
C     CORRECT FORMAT FOR THE CDC 6500 (PUNCHED)
C
C
C     BEFORE CONVERTING USING THIS PROGRAM ALL WRITTEN STATEMENTS
C     IN THE IBM 360 SERIES PROGRAM MUST FIRST BE CONVERTED TO THE
C     "H" FORMAT.
C
C
C     WHEN CONVERSION TO THE "H" FORMAT HAS BEEN MADE THEN THE
C     USER INSERTS HIS SOURCE DECK AS THE "DATA" FOR THE PRECEDING
C     PROGRAM  AFTER:
```

```
C
C        1.  REMOVING ALL SYSTEM CONTROL CARDS,
C
C        2.  REMOVING ALL SOURCE PROGRAM "DATA" CARDS.
C
C
C
C
```

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13. ABSTRACT

There is a need for a fast method of analyzing bathythermograph traces and this need is approached by the means of a high-speed digital computer. The theory behind the computer program is outlined. Both synthetic and real data cases are run as examples using both data card decks and magnetic tape inputs. The program has been designed to read digitized bathythermograph traces and then analyze them objectively by Gaussian and non-Gaussian methods for the top, center, and base of the main thermocline. Additionally, such features as multiple thermoclines, inversions, and thermal transients are identified also and their key points are included in the informational data printout.

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Thermocline						
Bathythermograph						
Magnetic Tape						
Digital Analysis						

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